ENERGY AUDIT STUDY

at

BHARAT ELECTRONICS LIMITED
BANGALORE

UNDER
INDIA-EC ENERGY BUS PROGRAMME

Sponsored by

ENERGY MANAGEMENT CENTRE
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BHARAT ELECTRONICS LIMITED
BANGALORE

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SECTION - I

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

Energy efficiency study was conducted by a team of engineers from Tata Energy Research Institute on the request of the management of BEL, Bangalore. The study was conducted in 1) T V tube plant 2) Gas plant 3) I C Plant and 4) Services including compressed air systems.

The purpose of this study is to identity energy saving opportunities. However, it does not concentrate on long term measures and large investment opportunities. The study was carried out with the help of Energy Management Cell and the plant personnel from the respective divisions of BEL. Instruments from the TERI's energy bus were used to measure different parameters at various energy consuming centres and equipments.

The study reveals numerous energy saving opportunities. The summary of which is presented below:

SUMMARY OF RECOMMENDATIONS

I. T.V.PLANT - I		Savings per annum	
		Savings (Rs.)	Investment (Rs)
1.	Effective insulation of baking oven	75,000	40,000
2.	Proper sizing of blower motors of Baking oven	26,000	65,000
3.	Reducing the inlet opening area of the baking oven	8,500	Minimal
4.	Avoiding the empty run of the Conveyor (Baking oven)	Not quantified	
5.	Closing both ends of the Baking oven at the end of the day	13,000	Minimal
6.	Alternate shield over the tubes	54,000	N.I
7.	Improving the exhaust oven insulation	1,00,000	40,000
	TOTAL	2,76,500	1,45,000

I. T V PLANT - 2

8.	Proper sizing of blower motors	22,000	70,000
9.	Improving the insulation	75,000	40,000
10.	Switching off burners during lunch intervals to save butane (Sealing zone)	Not quantified	
11.	Replacing the combustion air with Oxygen rich air from Gas plant	To be worked out	
12.	Close all the doors and windows of Air-conditioning rooms	N.Q.	Minimal
11.	Running only the cooling towers during months of winter and putting off the compressors	1,40,000	Minimal
	TOTAL	2,37,000	1,10,000

II. GAS PLANT

1.	For all the 3 Nitrogen Plants - replacement of deteriorated insulation in the absorber system	73,000	Tobe worked out
2.	Insulation of the hand holes/man holes in the absorber system	29,000	10,000
3.	Regular maintenance of inter coolers and after coolers	58,000	No Invstmt
4.	Heat recovery by process integration by installing air to air heat exchanger	2,10,000	2,40,000
5.	Chilled air intake to air compressors	15,00,000	12,00,000
		18,70,000	14,50,000

III. COMPRESSED AIR:

1.	Taking air from outside	1,48,000	40,000
2.	Changing the Transformer tap positions to give optimum voltage to the compressors	Not quantified	
3.	Stopping leakage and re-distribution of lines	- do -	
4.	Reducing the compressor air pressure	10 to 15%	Nil
5.	Thyristor controllers & variable speed drives	Not quantified	

V. IC PLANT

1.	Cleaning of chillers	12,30,000	Nil
2.*	Maintenance of compressors, checking discharge valve, etc.,	Not quantified	
3.*	Running of minimum no. of compressors at full load COP	"	
4.	Variable speed motor drives for reduction in capacity of compressors without unloading the cylinders	10% of the kWh on low loads	T.I
5. *	Cleaning of condensers	20% of kWh for fouled condensors	N.I
6. *	Maintenance and cleaning of cooling towers	Not quantified	Nil
7.	Installation of automatic cooling water temperature controller in sequence with cooling towers fan	To be investiaged	
8.	To produce chilled water by cooling towers during /dec/Jan. months	1,56,600	1,00,000
9.	*To carry out cooling in two stages,in months when the climatic conditions are favourable,First stage cooling in cooling tower and second stage in the chillers	Not quanti -fied	1,50,000

10.	By purging the non -condensibles from the condenser (Savings is given only for the condenser on which the test was carried out, for total savings the test should be carried out on all the condensers)	56,000	Nil
11.	Rectification of the temperature controllers on the air handling unit	Not quantified	
12.	Instrumentation & Monitoring log sheets for monitoring performance	-	-
13.	Automatic Monitoring system with micro electronic	-	-
	TOTAL	14,42,000	2,50,000
	GRAND TOTAL (All Plants)	39,73,000	20,00,000

* The energy savings for these recommendations can be estimated accurately, if proper instrumentation is employed in the system. A scheme for monitoring is recommended, based on the instrumentation.

SECTION II

INTRODUCTION
&
PLANT'S ENERGY MANAGEMENT

1.0 INTRODUCTION

A comprehensive energy efficiency study was carried out by a team of engineers from TATA Energy Research Institute (TERI) for over a period of 6 weeks starting from 4th March to 22nd of April, 1991.

The study was confined to the following units:

1) IC Plant
2) TV Tube Plant
3) Gas Plant and
4) Services division

The study was conducted by using the necessary instruments available with the energy auditing unit of TERI. Various parameters were measured and analysed along with the data provided by the plant personnel. The study was restricted to identify the energy management opportunities with low investments and where the pay back period is around 3 years. The observations and recommendations that are identified after the study are discussed seperately.

Assistance was provided by the energy conservation cell of BEL and the respective department personnel.

The energy conservation cell of BEL is highly motivated and has the active commitment of the top management with the necessary resources. The awareness on energy conservation was observed to be very good right from the highest management levels to the operating personnel and shift workers. There exists a good expertise with cell and among the plant personnel which needs to be translated into realities.

2.0 PLANT'S ENERGY MANAGEMENT:

The plant's energy input was analysed based on the data provided by the plant personnel. This data consist of the production figures of the various departments. Setting up of an energy management system would require actual consumption figures of major energy consuming departments with the production figures.

The annual purchased electricity bill of the entire plant is around Rs.438 lacs and the cost of generated electricity is around Rs.52 lacs. The plants contracted maximum demand is 14000 kVA. Among other energy inputs to the plant is LPG & HSD. HSD is mainly used for power generation and a small quantity is used in the boilers. The plant has self generating capacity of 11500 kVA and the annual HSD bill is around Rs.78 lacs. It is noted that the plants air conditioning alone consumes around Rs.48 lacs out of Rs.490 lacs per annum.

The monthly electricity consumption with the break-up of electricity purchase and generated is shown in graph1. It is seen that the generated energy is higher during the period of march, 90 to July 1990, which comprises of 48 % of the total energy generated during the 18 months under consideration.

It can also be seen from the same graph that the monthly electricity consumption is very consistant and varies between 40 lac to 32 lac units, with an average of 37 lac units per month. It is observed that the monthly electricity consumed in the year 1990 has been below 40 lac units except for the month of march 1990, which could be due to higher production.

The total power consumed during the period July to December 1989 is higher by 17 lac units (7.2%) when compared to the total power consumed during July-December 1990. This could be due to the various energy conservation schemes already adopted by the plant personnel.

Table I gives the monthly details of the power purchased, generated and specific energy generation ratio.

The monthly electrical demand variation is given in graph 2. It can be seen that the total demand of the plant has not exceeded 12,216 kVA during the period of 18 months under consideration. However, the contracted the maximum demand is 14000 kVA. The average demand over a period is 11095 kVA. The load factor calculated on this basis is 79.25 %.

Based on the half hourly readings taken on 12/13 April, 1991 for kW and kVA, the details of which are shown in figure 5 & 6. The load factor calculated on these readings is just 64.20 %. The demand curve and the load curve indicated that the power consumption rises sharply from 6 AM and peaks at around 10 AM and gradually falls of to minimum load after 10 PM.

It can be seen from graph 7 that the power factor varied between 0.86 to 0.97 for the day 12/13 April, 1991. The variation in the P.F. is quite low even when the load variation during the day flucuated between 2200 kVA to 9000 kVA. It can be inferred from this that the electricity utilisation is efficient.

The specific energy generation ratio for the period of 18 months under study is plotted in graph 3. It is inferred from the graph that the Specific Energy Generation Ratio (SEGR) was on the decline from 3.2 kWh/lit in July 1989 to 2.4 kWh/lit in Nov 1989 and has remained study throughout the year 1990 giving 3.1 kWh/lit except for the month of May, 1990 which was 3.18 kWh/lit. The reason for low SEGR could be due to under loading of the DG sets.

The department wise energy consumption is shown in figure 2. It can be seen that the gas plant consumes around 7 lac units, IC plant 6 lac units, TV tube plant 5.5 lac units, Silicon Devices 2 lac units and all the other small departments put together constitute around 17 lac units of electricity per month.

Table - 1

BHARAT ELECTRONICS LIMITED, BANGALORE

	PURCHASED ELECTRICITY			GENERATED ELECTRICITY			TOTAL			HSD		Sp.energy generation
MONTHS	ENERGY kWh	DEMAND kVA	COST Rs.lacs	ENERGY kWh	DEMAND kVA	COST Rs.Lacs	ENERGY kWh	DEMAND kVA	COST Rs.Lacs	kL	COST Rs.Lacs	kWh/Litre
Jul89	3590208	9720	37.61	304600	1760	6.09	3894808	11480	43.70	95.18	3.75	3.20
Aug89	3708720	9720	38.56	364200	1430	7.28	4072920	11150	45.84	117.48	4.63	3.10
Sep89	3790512	11016	40.34	279800	1200	5.60	4070312	12216	45.94	93.26	4.58	3.00
Oct89	3529626	9720	37.58	154700	1250	3.10	3684326	10970	40.68	53.00	2.09	2.92
Nov89	3640392	10296	38.78	135300	1500	2.71	3775692	11796	41.49	56.65	2.23	2.39
Dec89	3366147	9720	36.46	455000	1880	9.10	3821147	11600	45.56	151.32	5.97	3.01
Jan90	3391371	9360	35.62	355200	1250	7.10	3746571	10610	42.72	114.50	4.40	3.10
Feb90	3222186	10224	34.44	294200	600	5.88	3516386	10824	40.32	94.90	3.74	3.10
Mar90	3113181	9216	28.12	960300	1780	19.21	4073481	10996	47.33	309.79	12.22	3.10
Apr90	3087589	9144	32.95	489600	1760	9.79	3577189	10904	42.74	157.90	7.31	3.10
May90	3115707	9072	33.10	764000	1760	1.53	3879707	10832	34.63	240.25	11.12	3.18
Jun90	3208171	8856	33.86	639500	1530	2.79	3847671	10386	36.65	206.29	9.55	3.10
Jul90	2957036	10100	31.68	978900	1200	19.58	3935936	11300	51.26	315.77	14.62	3.10
Aug90	2993253	8928	31.95	283800	1200	5.68	3277053	10128	37.63	91.55	4.24	3.10
Sep90	3223769	9720	34.37	241400	1200	4.83	3465169	10920	39.20	77.87	3.61	3.10
Oct90	3148992	9000	48.42	332200	1200	6.64	3481192	10200	55.06	107.15	4.96	3.10
Nov90	3242466	10500	48.19	473300	1200	9.57	3715766	11700	57.76	152.65	8.75	3.10
Dec90	3268510	10500	48.67	489900	1200	9.80	3758410	11700	58.47	158.03	9.06	3.10
TOTAL	59597836	174812	670.70	7995900	24900	136.28	67593736	199712	806.98	2593.54	116.93	3.08

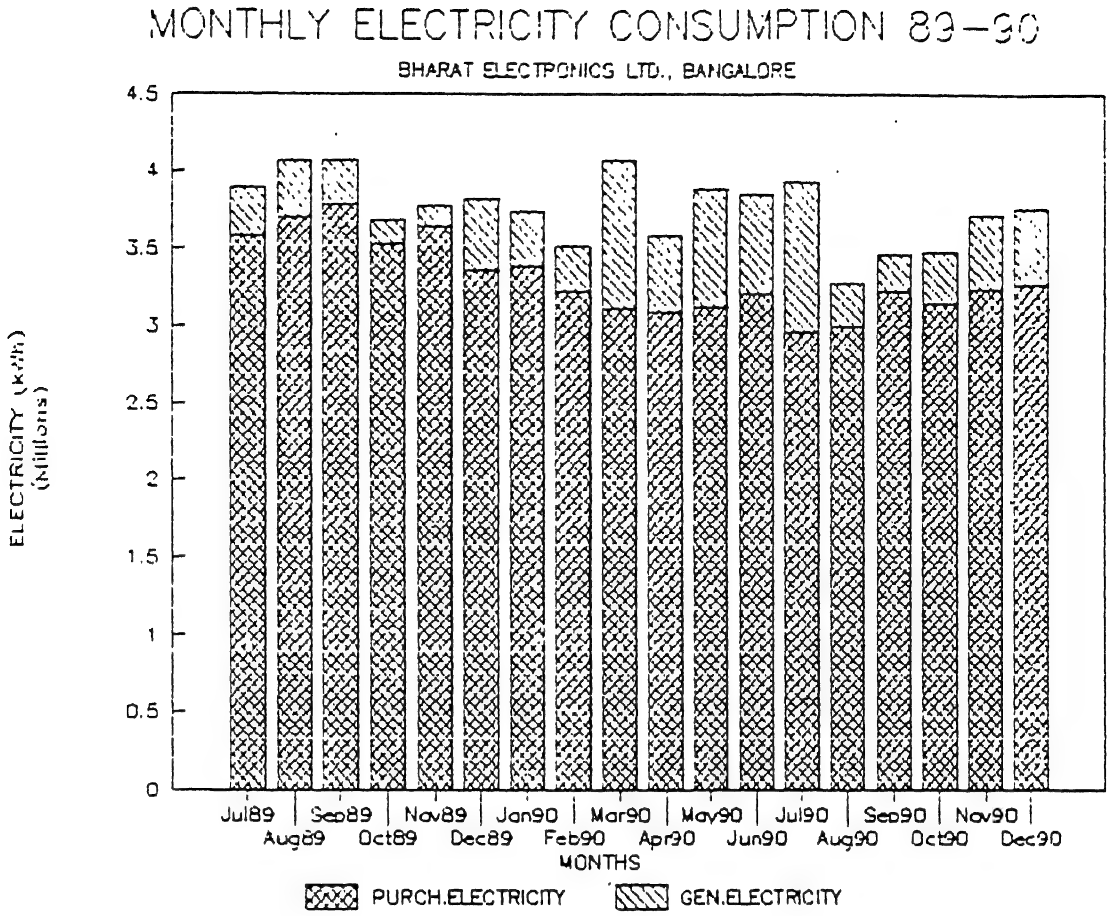
MONTHLY ELECTRICITY CONSUMPTION 89-90
BHARAT ELECTRONICS LTD., BANGALORE
ELECTRICITY (kWh)
(Millions)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jul89
Aug89
Sep89
Oct89
Nov89
Dec89
Jan90
Feb90
Mar90
Apr90
May90
Jun90
Jul90
Aug90
Sep90
Oct90
Nov90
Dec90
MONTHS
PURCH.ELECTRICITY
GEN.ELECTRICITY

Fig. 1

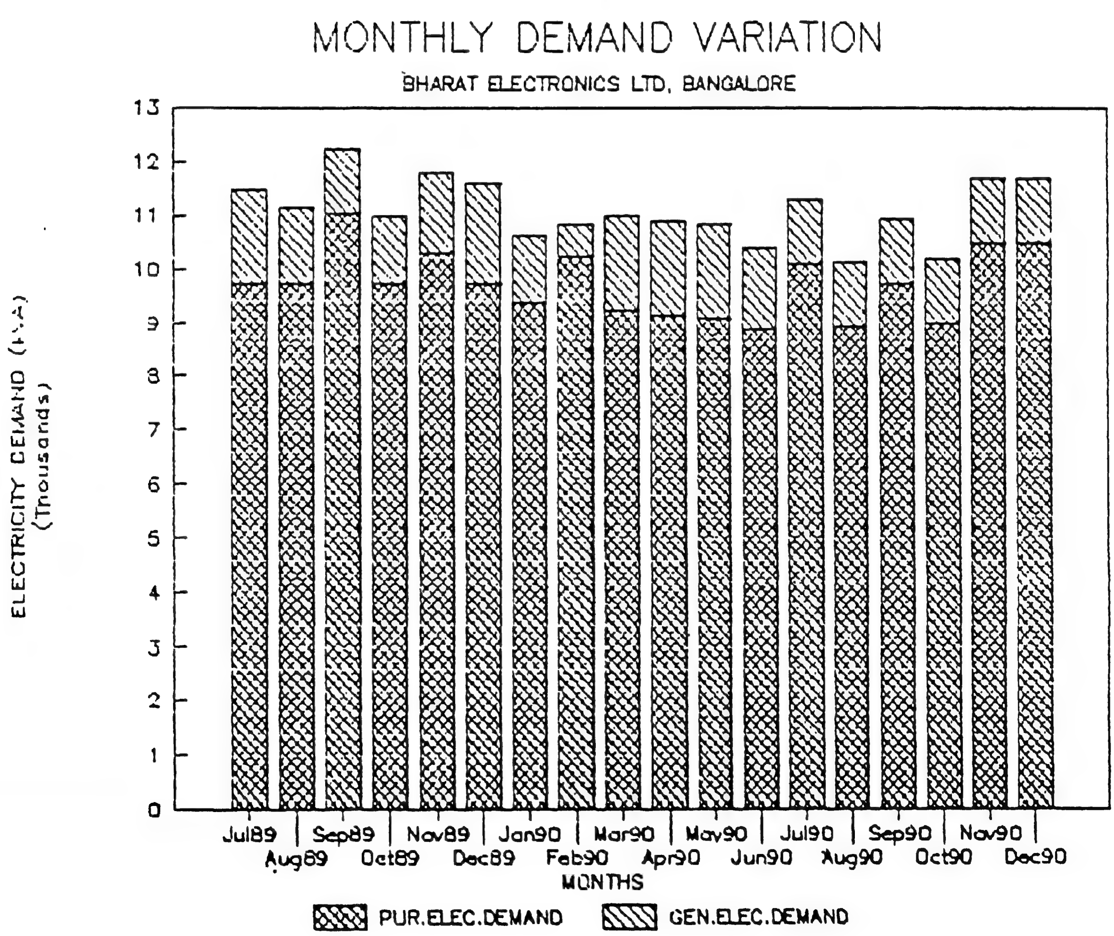
MONTHLY DEMAND VARIATION
BHARAT ELECTRONICS LTD, BANGALORE
ELECTRICITY DEMAND (KVA)
(Thousands)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Jul89
Aug89
Sep89
Oct89
Nov89
Dec89
Jan90
Feb90
Mar90
Apr90
May90
Jun90
Jul90
Aug90
Sep90
Oct90
Nov90
Dec90
MONTHS
PUR.ELEC.DEMAND
GEN.ELEC.DEMAND

Fig 2

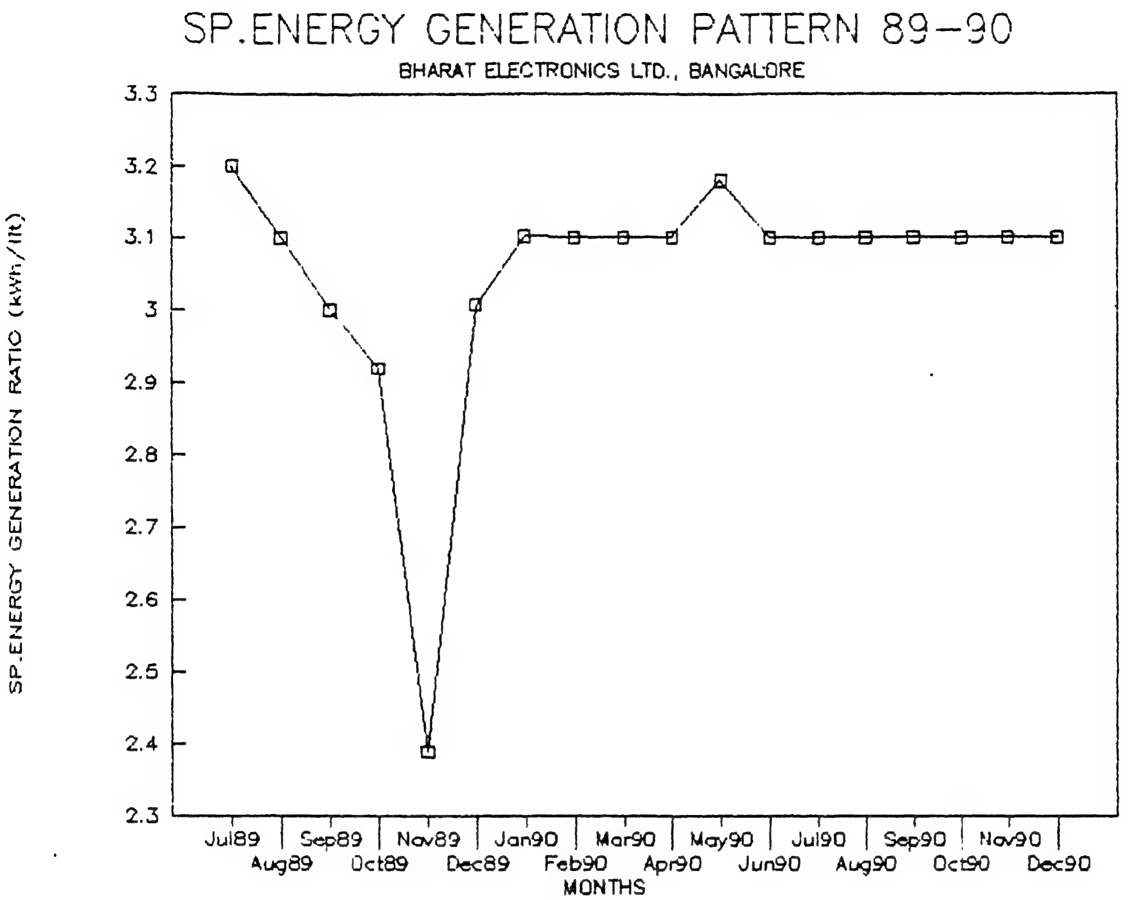
SP.ENERGY GENERATION PATTERN 89-90
BHARAT ELECTRONICS LTD., BANGALORE
SP.ENERGY GENERATION RATIO (kWh/lit)
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
Jul89
Aug89
Sep89
Oct89
Nov89
Dec89
Jan90
Feb90
Mar90
Apr90
May90
Jun90
Jul90
Aug90
Sep90
Oct90
Nov90
Dec90
MONTHS

Fig.3

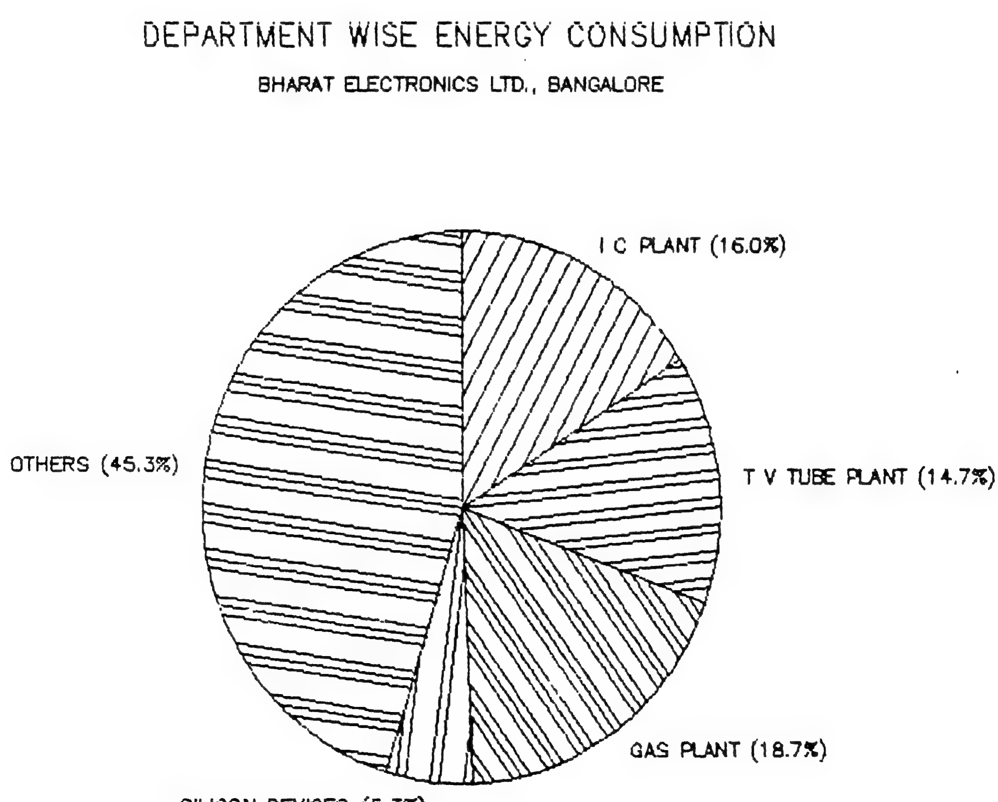
DEPARTMENT WISE ENERGY CONSUMPTION
BHARAT ELECTRONICS LTD., BANGALORE
I C PLANT (16.0%)
T V TUBE PLANT (14.7%)
GAS PLANT (18.7%)
SILICON DEVICES (5.3%)
OTHERS (45.3%)

Fig.4

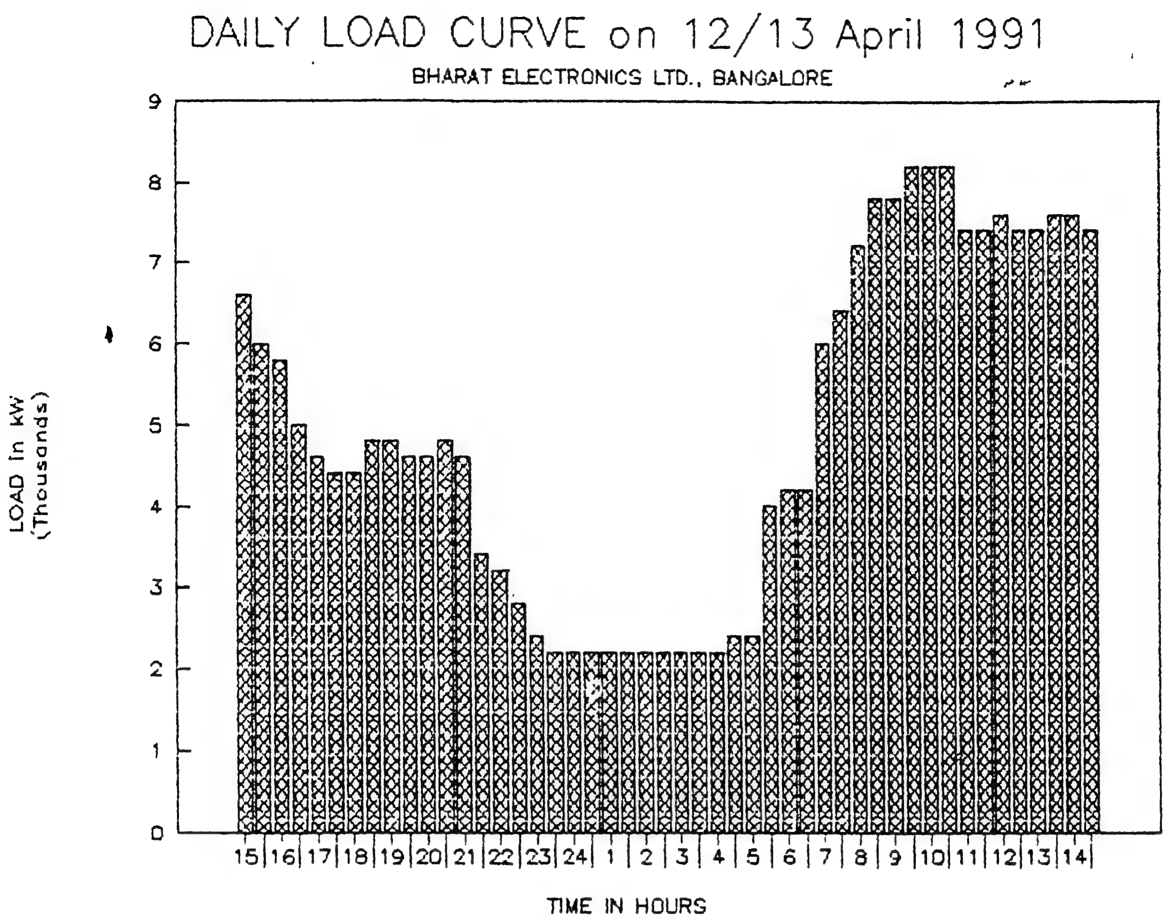
DAILY LOAD CURVE on 12/13 April 1991
BHARAT ELECTRONICS LTD., BANGALORE
LOAD In kW
(Thousands)
0
1
2
3
4
5
6
7
8
9
15
16
17
18
19
20
21
22
23
24
1
2
3
4
5
6
7
8
9
10
11
12
13
14
TIME IN HOURS

Fig.5

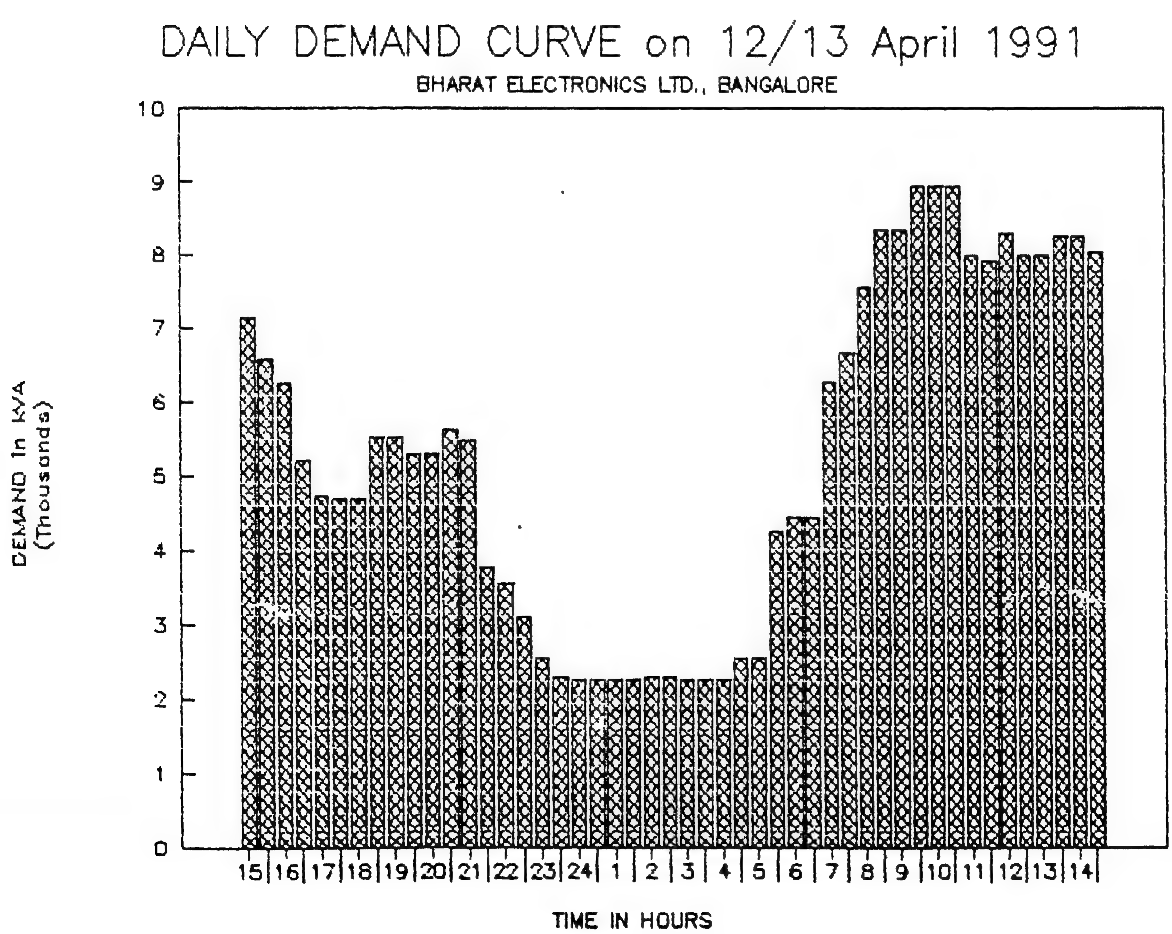
DAILY DEMAND CURVE on 12/13 April 1991
BHARAT ELECTRONICS LTD., BANGALORE
DEMAND In kVA
(Thousands)
0
1
2
3
4
5
6
7
8
9
10
15
16
17
18
19
20
21
22
23
24
1
2
3
4
5
6
7
8
9
10
11
12
13
14
TIME IN HOURS

Fig.6

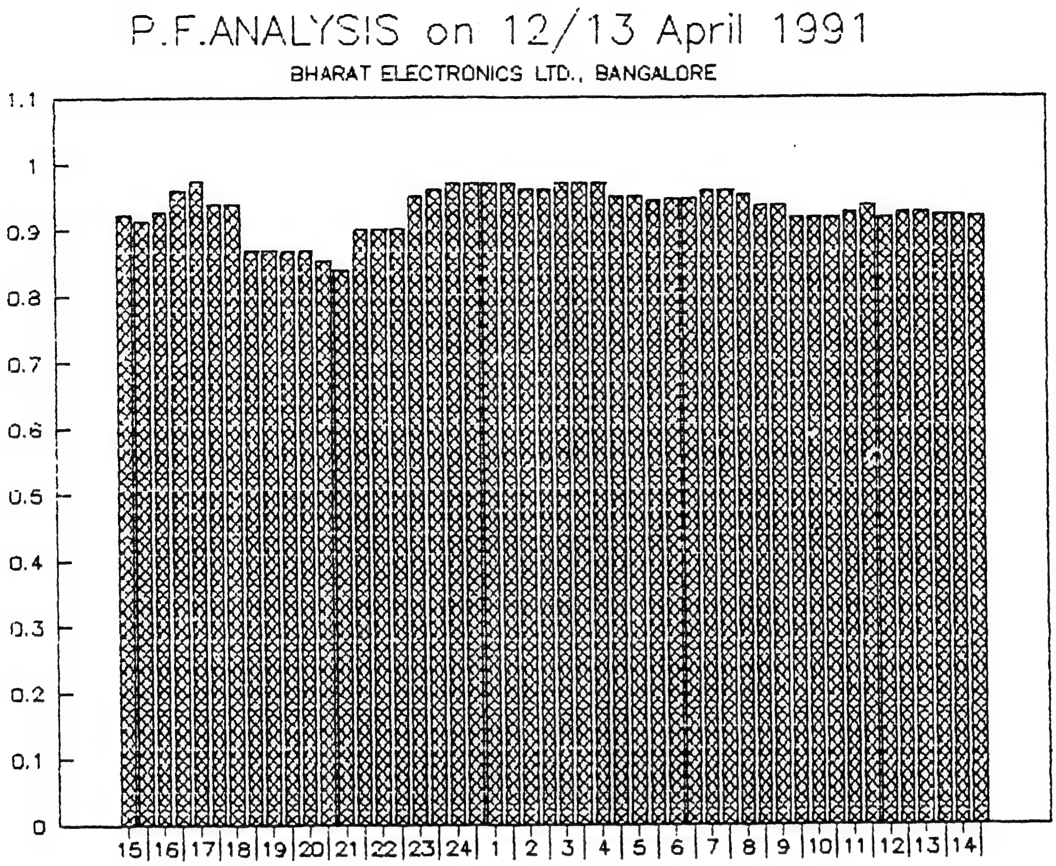
P.F.ANALYSIS on 12/13 April 1991
BHARAT ELECTRONICS LTD., BANGALORE
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
15 16 17 18 19 20 21 22 23 24 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Fig. 7

T V PLANT

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T V TUBE PLANT

INTRODUCTION:

There are two TV tube plants in the complex, plant I that makes 20" tube processing and the plant II that makes 14" and monitor tubes. The primary input material, the 20 " glass shells are brought from BEL Taloja unit, while for plant II the 14" glass shells are imported from SUMITOMO Japan.

The raw bulb undergoes various processes like washing , screen coating, lacquering, aluminising, baking at a maximum temperature of 440°C., electron gun sealing, exhausting at a maximum temperature of 420°C., HT & LT ageing, Banding, and inspection before it comes out as a finished product.

In 1989-90 the plant produced 5.44 lakh tubes against a plant capacity of 8 lakhs amounting to a sales turn over of 29.77 crores.

The total monthly energy consumption of the plant is around 6,43,520 units of electricity. The monthly electricity consumption pattern for the year 1990 is shown in graph 1 and table 1A. It can be seen from the table that the average monthly energy consumption in the year 1990 came down by about 12.5 %. The reason for this could be production related.

The process equipment wise energy consumption in the department is shown in the pie chart for both TV Plant I & TV Plant II. It can be seen from the the charts that both baking oven and exhaust oven take away the lions share of the plants energy consumption amounting to 62.2% in TV Plant I and 61.2% in TV Plant II.

The specific energy consumption of the plant is shown in the bar graph attached. It is evident that the plants specific energy consumption has comedown from 12.2 kWh/tube during 1989-90 to 11.1 kWh/tube during 1990-91. This reduction is attributed to the departmental energy conservation measures effectively adopted by the plant personnel.

After analysing the energy consumption pattern departmentwise it was decided to concentrate on the following major energy consuming plant items.

1) Baking ovens

2) Exhausting ovens

3) Air conditioning

In general the standards of awareness on energy conservation were observed to be very high right from the top management to the operators level. A lot of posters can be seen in the plant cautioning "We have a long way to go ....Conserve energy." The record maintenance of the plant was very good and the plant executives have been regularly analysing various parameters that directly affect the energy consumption.

1.0 BAKING OVEN (TV Plant I)

The 20" tubes after the process of aluminising are fed into the baking oven to evaporate the lacquer that is present in the tubes and for annealing the tube at a maximum temperature of 440°C.

The oven, 18 years old Bengall Inn make, has 21 zones with zone temperatures varying from 110°C in the first zone to 440°C in the ninth zone and 130°C in the last zone. The oven is designed to attain the rate of heating at 25 °C/min and rate of cooling at 8°C/min. The heating process takes place from the I zone to X zone and the cooling process from XI to XXI zone. The tube that enters the oven at room temperature finally comes out at around 100°C. The oven has 11 blowers mounted on the roof to recirculate the hot air in the respective zones. The oven is operated 2 shifts, 16 hours per day with initial heating period of approximately 90 minutes.

The oven consumes 320 kWh per batch of tubes in 140 minutes ater reaching steady state conditions. The total number of tubes that form a batch are 250.

OBSERVATIONS & RECOMMENDATIONS:

The oven efficiency is calculated to be 54 %. The loss due to convection & radiation account for 14 % while the heat loss due to heat taken by the conveyor and other leakages account for 32 %.

1.1 It can be seen from the energy balance that the heat loss due to Convection and radiation is very high accounting for 44 kWh (14 %) of electricity per batch. The surface temperatures from V zone to XVI zones are very high with a maximum temperature of 102°C near zone XI and XII. The bottom portion at the oven inlet is very poorly insulated and the surface temperature measured was 92°C.

It is recommended to insulate the oven effectively with glass wool or mineral wool and monitor the quality of insulation periodically. The energy savings possible from this would be 30 kWh per batch (assuming 80 % effective insulation) and 54,000 units of electricity amounting to Rs.75,000 monetory savings per annum.(Assuming 6 batches per day,300 days/year and Rs.1.40/kWh).

1.2 The opening at the oven inlet is 2 mts length by 0.54 mts height, where as the tube when placed on the major axis would come to about 0.34 mts only. The hot air in the first zone was measured to be at 176 ^{o}C.

It is recommended to reduce the inlet opening area by closing 2 mts X 0.15 mts from the top to minimise th direct contact between the hot air in the first zone and cold air outside. The estimated savings would be around 6000 units per year.

1.3 The loading on the blower motors has been measured by the clip-on power analyser. The readings are tabulated in table.1.

It can be seen from the readings that there are two different capacities of motors installed. Blower No. 1 to 7 with 11 kW and blower No.8 to 11 with 5.5 kW. All the 11 kW motors are loaded upto 5 kW (max) except for the blower in the first zone and all the 5.5 kW motors are loaded upto only 2 kW (max).

It is recommended to replace all the blower motors except the blower in the I zone with smaller capacity motors i.e., with 5.5 kW and 2.2 kW motors on a maintenance schedule and observe the performance. If the blowers of lower capacities are available elsewhere in the plant it is recommended to replace the 11 kW blowers with lower capacity blowers. The energy savings would be 18,500 units electricity resulting in Rs.26,000 of financial savings per annum.

1.4 The zonewise set temperature, actual temperature and the bulb temperature profile are given in tables 2 & 3 and the respective graphs. It can be seen from the bulb temperature profile graph that the bulb temperature overshoots upto 466^{o}C whereas the maximum temperature requirement is only 440^{o}.

It is also observed from the heat distribution graph that the rate of heating is around $10^{o}C/min$ as the required rate is $25^{o}C/min$ and the rate of cooling is only $4.4^{o}C/min$ where as the desired rate of cooling is $8^{o}C/min$. It is recommended to investigate the process in detail and lower the heater capacities in the cooling zone.

It can also be seen from table 3 that the increase in bulb temperature for 20-25 minutes of operation was $132^{o}C$, and the drop in temperature from $139^{o}C$ after 20 minutes to $101^{o}C$ after 25 minutes of starting and sudden increase in the cooling zone from 52 to 68 and $80^{o}C$.

It is suggested to recalibrate all the temperature indicators and monitor the functioning of the thermocouples periodically to avoid misleading information regarding zone temperatures. This helps in analysing the zone temperatures and arriving at the exact set temperatures to achieve the optimum bulb temperatures thereby saving considerable energy.

1.5 It was noticed that some portion of the oven often goes empty, the intermittent stoppages of the conveyor chain during the lunch/tea intervals and at shift change over period.

It is recommended to stagger the timings of the operators so that the conveyor chain is run continuously and the volumetric heat of the oven is utilised fully. This helps in avoiding the over heating of any particular zone and get more number of tubes throughput for a given energy input.

1.6 It was understood from the plant executives that presently both the ends of the oven are kept open when the oven is switched off during end of the day. It should also be noted that the air in the first zone is at a temperature of $176^{o}C$.

It was suggested to close both ends of the oven with an asbestos cover when the oven is switched off. This measure helps in avoiding the cold air infiltration that dilutes the inside hot air when the blowers are all switched off. The energy input requirement to reheat the oven the next day will be considerably less as most of the heat in the oven is retained inside.

Tests are being carried out by the plant personnel to see the exact difference when the oven is covered both ends and when it is not covered. The exact quantification of the energy savings with this measure can be arrived at only after the completion of these tests. However experience shows that there would result an approximate savings of around 9500 units per annum.

2.0 EXHAUST OVEN (TV PLANT I)

There are two exhaust oven of similar capacity. Only one exhaust oven i.e., Exhaust oven 'B' is studied as the same suggestions can be applied for the other exhaust oven also.

The basic function of exhausting oven is for degassing the sealed tubes by creating a vacuum of 10^{-4} torr inside the tubes, at a maximum temperature of 420°C. The maximum set point temperature is 500°C and the actual bulb temperature achieved is around 400°C.

The tubes mounted on a cart equipped with vacuum pump and other water cooling equipment are passed through all the zones of the oven. A metallic shield is also provided to cover all the tubes to avoid the breakage of adjascent tubes when any particular tube is imploded. 64 carts will pass through the oven per batch and it takes around 2 hours per batch of operation. The oven is operated for 24 hours and the energy consumption is around 150 kWh per batch. The weight of each bulb is 8 kg and that of the shield and frame is also 8 kg.

The zone wise temperature profile is given in table 4.

The energy balance of the oven is given below:

Heat supplied	=	150 kWh	(100 %)
Heat given to bulbs	=	40.27 kWh	(26.85 %)
Heat lost to shield and frame	=	37.36 kWh	(24.91 %)
Heat lost to convection and radiation	=	28.64 kWh	(19.09 %)
Heat lost to cart, blower, air and other leakages	=	43.73 kWh	(29.15 %)

OBSERVATIONS & RECOMMENDATIONS

2.1 It can be seen from the energy balance that heat lost to shield & frame accounts for 25 %of the energy input which is very high.

It is suggested to explore the possibility of placing the shield covers on the tubes alternatively to meet the safety requirements and to reduce the heat loss. It is calculated that the heat taken away by the shield cover alone accounts for 25.6 kWh. This can be reduced to 12.6 kWh if the shield covers are placed alternatively. This measure saves energy to the extent of 39,000 units of electricity and financial savings of Rs.54,600 per annum.(Assuming 24 hours of operation, 10 batches per day, 300 days, and Rs.1.4 per unit of electricity)

2.2 Though the insulation was done recently, it was observed that the insulation levels are very poor on bottom and top slopy roofs. The maximum temperature observed was 123^{o}C on the bottom slope near zone IV and 146^{o}C on top slope near zone V. The surface temperatures on the sides are at an average value of 55^{o}C which is again 15^{o}Cmore than the allowable value.

The energy balance of the oven reveals that the loss due to radiation and convection acounts for 28 kWh i.e., 19% of the energy input which is very high. It is recommended to insulate the sides top and bottom portion effectively with glass wool or mineral wool. The energy savings after 80 % effective insulation would come to 72,000 units of electricity resulting in over one lakh rupees savings per annum.

3.0 BAKING OVEN (PLANT II)

This oven is completely designed and developed by the BEL executives and it has necessary modifications that were suggested for TV Plant I. The function of this oven is same as in the plant I with the difference that the input will be 14 " tubes instead of 20 " tubes.

The efficiency is calculated to be at 37 % with 13% accounting for heat loss due to convection and radiation. The remaining 50 % heat goes in heating the conveyor chain, air and other leakages.

OBSERVATIONS & RECOMMENDATIONS

3.1 The suggestion of closing both the ends of the oven when it is switched off can be implemented for this oven also.

3.2 It can be seen from the energy balance that the bulk of the heat is unutilised as 50 % of the heat goes to heat the air to maintain the zone temperature, heating the conveyor chain and other associated leakages.

In the long run it is advisable to explore the possibilities of reducing the weight of the conveyor chain preferably with a lesser conducting material for the same strength.

3.3 The insulation levels of the oven were observed to be better than that of plant I. But still it is recommended to insulate the hot zones from III to XII which have the surface temperature more than 60 ^{o}C. The bottom portion at the inlet of the oven is also measured to be at 61 ^{o}C and needs to be insulated. The energy savings that could be achieved even if the 80% of these losses are stopped with effective insulation would be 54,000 kWh of electricity and Rs.75,000 per annum.

3.4 The loading on the blower motors has been measured using a clip-on-power analyser. The readings are tabulated in table 1. It can be seen from the table that the blower motors are completely underloaded and the power factor varies from 0.30 to 0.54.

It is recommended to replace all 7.5 hp blower motors with 3 hp motors or replacing with any lower capacity motors that are available else where in the plant. All the motors can be replaced with 3 hp motors except the first two motors. This measure saves energy to the extent of 16,000 units of electricity resulting in a monetory savings of Rs.22,600/- per annum.

3.5 The staggering of the operator lunch/tea intervals is suggested to this plant also to avoid the overheating of any particular zone and underutilisation of the oven volumetric heat load.

4.0 EXHAUST OVEN (TV PLANT II)

There is only one exhausting oven in plant II unlike in plant I where there are two exhaust ovens. This oven processes 126 tubes per batch and consumes around 300 kWh of electricity. It was observed that the energy consumption was not consistent as it recorded 300 kWh for one batch, 210 kWh for another batch and 400 kWh for the third batch of operation under similar conditions.

It is recommended that the functioning of energy meter be checked and calibrated periodically.

Because of the variations in the energy meter reading the energy balance for this oven was not calculated as the efficiency comes to only 12 % with an average energy input of 300 kWh.

It is observed that bulk of the heat goes in heating the supporting stand as the weight of the stand would be more than the bulbs and part of the heat in heating the air inside the oven to maintain th zone temperature. It is suggested to replace the stand structure with a lesser weight material and low specific heat like polyurethene. The savings achieved would be substantial. The quantification was not possible as the data was insufficient.

The insulation levels have to be improved as the average surface temperature was around 60^{o}.

5.0 ANALYSIS OF OVEN OPERATION

Temperature profiles were plotted with respect to the zones and time for the both the baking ovens. Temperature profiles were also plotted for rate of cooling after the oven was switched off for the day and the rate of heating during the initial start-up.

5.1 It can be seen from the zonewise temperature profile of TV plant I (Graph 5), that the zone wise temperature set points are maintaining the required zone temperature profile. However the rate of cooling from zone 10 to zone 11 is much faster which amounts to 75°C instead of 25°C as set, which is harmful to the quality of the tubes. This could be of because of various reasons which needs to be investigated. This rapid drop in the cooling zone can confirmed from the bulb temperature profile as shown in graph 6.

5.2 It is evident from the graph 7 & 9 that the heat retained within the oven of TV plant I is considerably high compared to TV plant II as indicated by the temperature profile at different zones before initial start-up. Although the heat retained in TV plant I is high the, kWh consumed to achieve steady state was much higher than TV plant II where the initial temperature were very low.

5.3 Graph 7 reveals that the temperatures in zone IX reached to the maximum of 450°C from the initial temperature of 250°C within 30 minutes. It is suggested that the plant personnel look into this aspect in greater detail, if this is desirable or not.The temperatures required to reach the study state conditions can be reached much earlier when conmpared to TV plant II. The oven can be switched on only an hour before the normal feeding of oven which is likely to save considerable amount of energy.

5.4 Graph 11 indicates that the rate of cooling during the first one hour from zone 1 to 5 is practically negligible,whereas the temperature drop between zone 6 and 10 is considerable. This is supported by the surface temperature measurements of the oven. It is also observed that the temperatures between zone 10 to 13 shot up during the last one hour. This needs to be examined.

5.5 The energy consumption during the initial start-up varies from 220 kWh to 420 kWh as per the experiments carried out by the plant personnel. Since the variation is very large it is suggested to repeat the experiment to establish the correct energy consumption during the start-up.

6.0 SEALING ZONE

The sealing zones in both plant I & II are heated by burning butane with the help of compressed air. Different types of burners are located to heat the electron gun and the supporting frame while sealing.

It was observed that even during the lunch breaks and shift change over, all the burners were on even when the tubes are not in the operation.

It is recommended to control some burners while a few burners could be on to maintain the temperature of the supporting frame and the zone. It was not possible to quantify the savings with this measure as the butane consumption per hour was not available. However there will be considerable savings even when 8 burners were switched off for an hour i.e., during the lunch and dinner intervals.

The surface temperatures around the sealing zone were measured and observed to be in the reasonable limits. It was also felt that majorty of the heat is lost through the openings from the top.

Considerable savings can be achieved by 1) the use of oxygen rich air which is a waste gas in the nitrogen plant, 2) by a detailed study of the temperature profiles required with in the sealing zone and providing top covers and regulating the flow of combustion gases through a duct.

7.0 AIR CONDITIONING

Air conditioning is provided in both the plants in the departments of bulb coating, lacquering and aluminizing. There are two systems of 80 tons and 120 tons of air conditioning systems installed in the plant I, but most of the time only 80 tons system is operated depending upon the load. Chilled water is supplied to both the process requirements and for air handling units.

In plant II there is only one 40 tons air conditioning system. The desired air conditioning levels required for all the departments in both plant I & II are as follows:

Relative Humidity = 55 ± 5 %

Temperature = $25 \pm 2^{o}C$.

MEASUREMENTS

The measurements of Relative Humidity and the room temperatures measured by using an electronic digital Humidity meter are listed below:

Department	% RH	Temp (^{o}C)
TV I:		
Bulb coating	48.8	27.8
Lacquering	51.6	27.2
Aluminising	52.5	26.9
TV II:		
Coating & Lacquering	50.3	26.7
Aluminising	51.8	27.4

OBSERVATIONS & RECOMMENDATIONS

6.1 It was noticed in TV PLANT I that all the doors and the windows in the air conditioning area are left opened. The ouside departments that are not air conditioned are observed to be with RH = 45.2% and temperature at 27.3°C. It can be seen from the readings taken that the difference between the areas that are air conditioned and that are not air conditioned is not much. The reason for this can be attributed to the large openings of the air conditioned area resulting in air infiltration and increasing the load on the air conditioning system.

It is recommended to close all the doors, windows and the other openings effectively to avoid the outside air infiltration and thereby reducing the load on the refrigeration system.

6.2 It was observed on a typical operating day that the difference between chilled water inlet and out let temperature is only 1°C. This means that there is no chilling taking place in the evaporator and there is no need to run the refrigeration system at all. It is suggested to probe in to the system and switch off the compressor if the desired condition is achieved with the chilled water inlet temperature only.

6.3 It was not possible to do the non-condensable test on the condenser to find out the exact amount of non condensables or air that are present in the condensor as there was no provision for the pressure gauges.

6.4 It is recommended during the winter to switch off the entire refrigeration system as it is possible to attain the chilled water temperature of 14 °C by running only the cooling tower.This is possible because during winter the wet bulb temperature would be around 12°C.

The savings achieved with this measure would be 1,00.000 units of electricity for both the plants, if the process is adopted for three months of winter.

ANNEXURES

BHARAT ELECTRONICS LIMITED

BEL TV TUBE PLANT

ELECTRICITY CONSUMPTION PATTERN 1989-90

Period	kWh consumed 1989	kWh consumed 1990
April	565815	502780
May	734730	526177
Jun	729060	604695
Jul	677232	556775
Aug	715436	509000
Sep	673630	536230
Oct	497900	551070
Nov	549220	550455
Dec	542040	643520

TV PLANT I

Dept	Units Consumed
AC plant	32325
Bulb processing	31691
Baking oven	68736
Exhaust Oven	91488
Emergency	57878
Others	68605
Total	350723

TV PLANT II

Dept	Units Consumed
AC plant	21375
Bulb processing	22816
Baking oven	71287
Exhaust oven	54002
Emergency	38586
Others	59815
Total	267881

TABLE 1

PERFORMANCE OF BLOWER MOTORS
BAKING OVEN

kW Rated	Loading pattern kW	kVA	P.F.	Amps	Volts
TV 1					
11	6.36	9.06	0.7	12	404
11	4.95	7.74	0.65	9	400
11	4.47	7.41	0.65	10.5	405
11	4.11	7.08	0.63	9	405
11	4.26	7.59	0.69	10.6	406
11	4.71	7.47	0.63	10.6	405
5.5	1.53	3.66	0.5	5.1	403
5.5	2.04	3.96	0.61	5.4	403
5.5	1.86	3.87	0.59	5.3	405
5.5	2.34	3.9	0.65	5.8	403
TV2					
5.5	2.46	4.77	0.45	6.6	408
5.5	2.25	4.35	0.4	6	414
5.5	1.92	4.35	0.36	5.7	415
5.5	1.89	4.2	0.43	5.6	415
5.5	1.77	4.44	0.37	5.6	415
5.5	1.65	4.11	0.34	5.4	416
5.5	1.8	4.38	0.35	5.8	416
5.5	1.77	4.53	0.33	5.8	417
5.5	1.92	4.2	0.35	6	415
5.5	1.2	3.66	0.3	5.4	416
5.5	0.93	4.35	0.33	5.4	416
5.5	0.93	4.35	0.35	5.6	416
5.5	1.17	4.35	0.43	5.7	415

SPECIFIC ENERGY CONSUMPTION PATTERN

PERIOD	Unit/tube
Apr-Dec 88	11.92
Jan89-Jan 90	12.2
Jan90-Jan91	11.1

BHARAT ELECTRONICS - BANGALORE

TV PLANT I

BAKING OVEN

Table 2

Zone No.	Set Temp	Actual Temp
1	100	110
2	140	150
3	210	230
4	300	295
5	350	360
6	370	355
7	385	360
8	430	430
9	430	450
10	430	420
11	410	340
12	370	330
13	330	300
14	310	300
15	290	290
16	260	280
17	250	250
18	220	230
19	190	160
20	160	160
21	130	100

Table 3

Time (min)	Bulb Temp
0	60
5	81
10	101
15	139
20	101
25	233
30	238
35	303
40	340
45	384
50	410
55	419
60	429
65	432
70	424
75	466
80	460
85	367
90	367
95	375
100	376
105	352
110	323
115	310
120	246
125	242
130	163
135	169
140	85
145	75
150	58
155	52
160	68
165	80
170	65
175	55

B E L TV PLANT II-BAKING OVEN

RATE OF COOLING

No.	Set Temp	6.45	7.15	7.45	8.15
1	110	170	170	170	120
2	200	240	240	250	190
3	300	320	330	330	280
4	370	390	370	370	330
5	420	410	410	400	370
6	440	440	420	390	370
7	440	440	410	380	360
8	420	420	400	380	350
9	400	400	360	340	330
10	380	370	350	320	300
11	360	350	320	290	280
12	240	270	290	330	340
13	300	290	250	220	200
14	260	240	200	170	160
15	200	190	160	150	140
16	150	140	120	120	100
17	100	100	100	90	80
18	50	90	90	90	70

RATE OF HEATING

Zone No.	5.15	6	6.45	7.3
1	30	110	130	150
2	50	160	220	240
3	40	180	310	320
4	40	200	380	400
5	50	200	380	440
6	60	170	330	410
7	40	150	310	410
8	50	140	270	380
9	50	180	320	400
10	50	180	330	380
11	50	190	340	360
12	60	200	340	340
13	50	200	300	300
14	50	180	240	250
15	50	180	210	210
16	40	170	160	160
17	30	140	110	120
18	40	90	60	100

BEL-TV PLANT I -BAKING OVEN

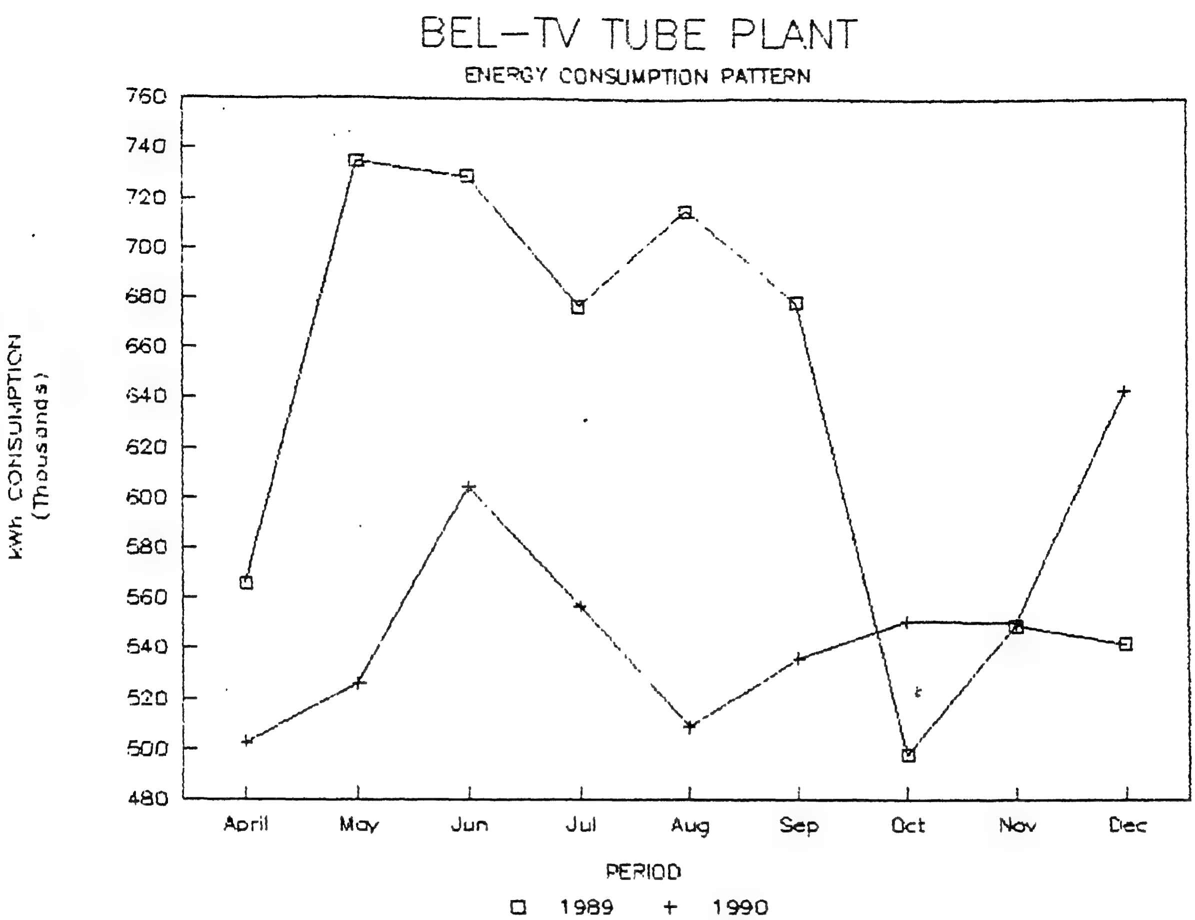
RATE OF HEATING

ZONE No.	5	5.3	6	6.45
1	80	110	100	100
2	85	100	100	110
3	150	230	230	230
4	210	300	300	300
5	250	330	350	350
6	200	270	295	330
7	190	220	260	360
8	240	290	350	420
9	250	450	450	450
10	260	330	370	430
11	260	300	320	360
12	240	280	360	350
13	210	240	270	300
14	200	240	290	300
15	220	250	280	290
16	220	250	260	260
17	190	200	210	220
18	170	190	200	210
19	120	120	120	130
20	130	140	140	140
21	70	70	70	70

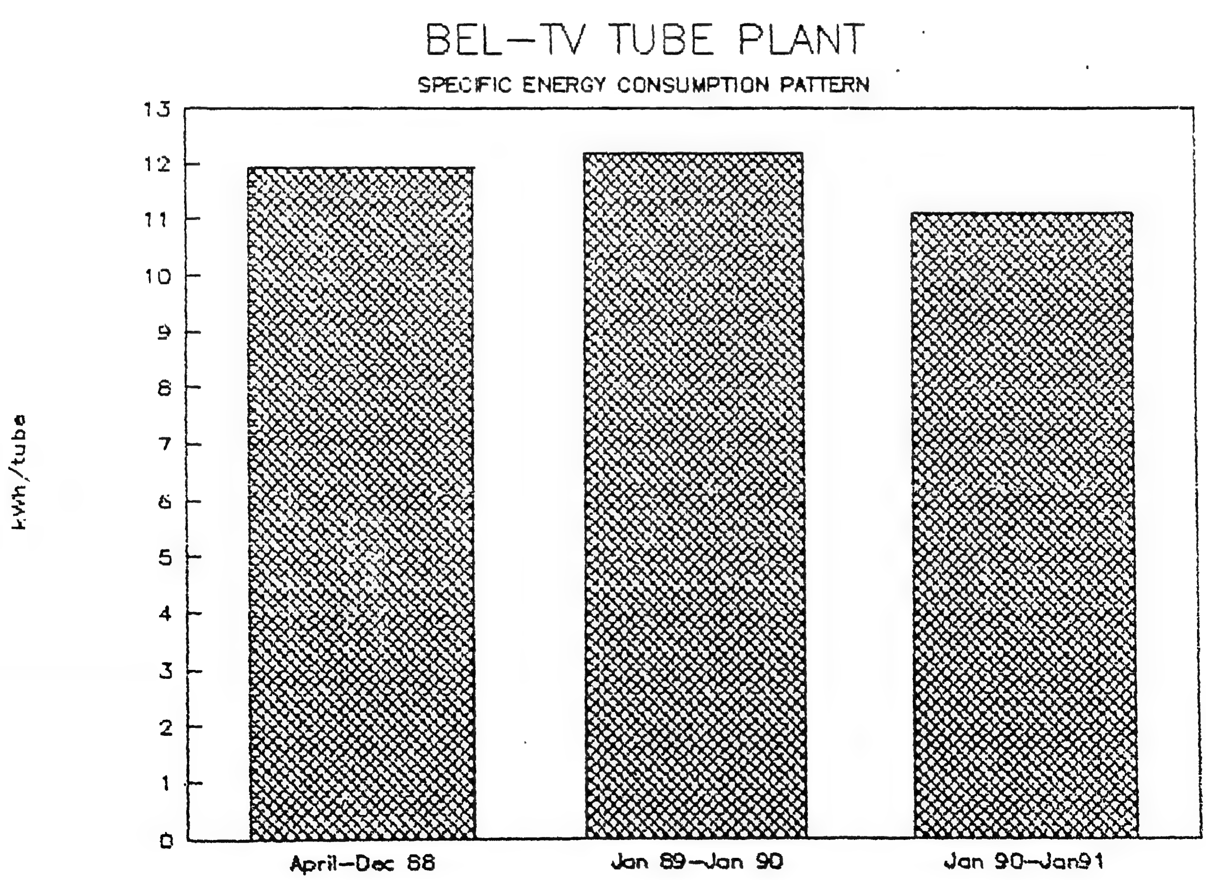
B E L TV PLANT II

BAKING OVEN

Zone No.	Set Temp	6.45	7.15	7.45	8.15
1	110	170	170	170	120
2	200	240	240	250	190
3	300	320	330	330	280
4	370	390	370	370	330
5	420	410	410	400	370
6	440	440	420	390	370
7	440	440	410	380	360
8	420	420	400	380	350
9	400	400	360	340	330
10	380	370	350	320	300
11	360	350	320	290	280
12	240	270	290	330	340
13	300	290	250	220	200
14	260	240	200	170	160
15	200	190	160	150	140
16	150	140	120	120	100
17	100	100	100	90	80
18	50	90	90	90	70

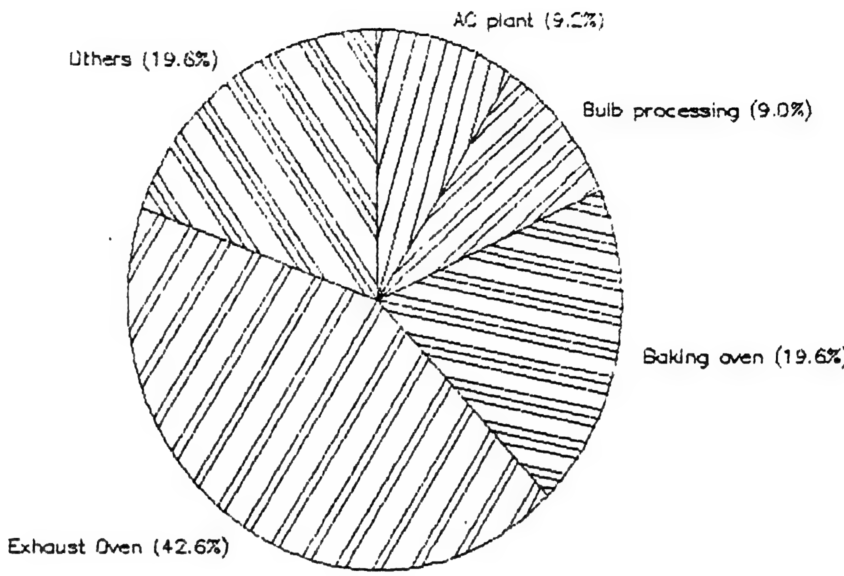

BEL-TV TUBE PLANT
ENERGY CONSUMPTION PATTERN
kWh CONSUMPTION (Thousands)
760
740
720
700
680
660
640
620
600
580
560
540
520
500
480
April
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
PERIOD
1989
1990

GRAPH 1


BEL-TV TUBE PLANT
SPECIFIC ENERGY CONSUMPTION PATTERN
kWh/tube
13
12
11
10
9
8
7
6
5
4
3
2
1
0
April-Dec 88
Jan 89-Jan 90
Jan 90-Jan91

BEL-TV PLANT1

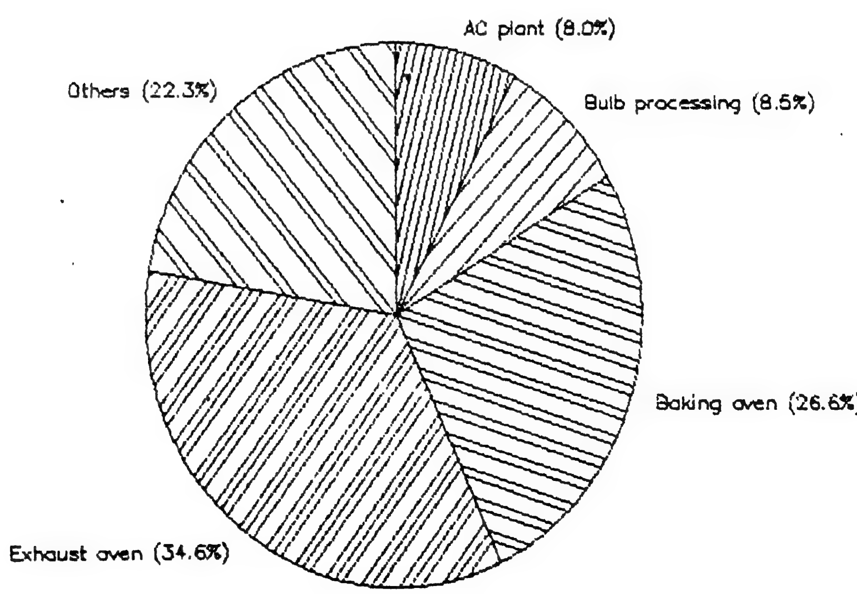
ENERGY CONSUMPTION PATTERN



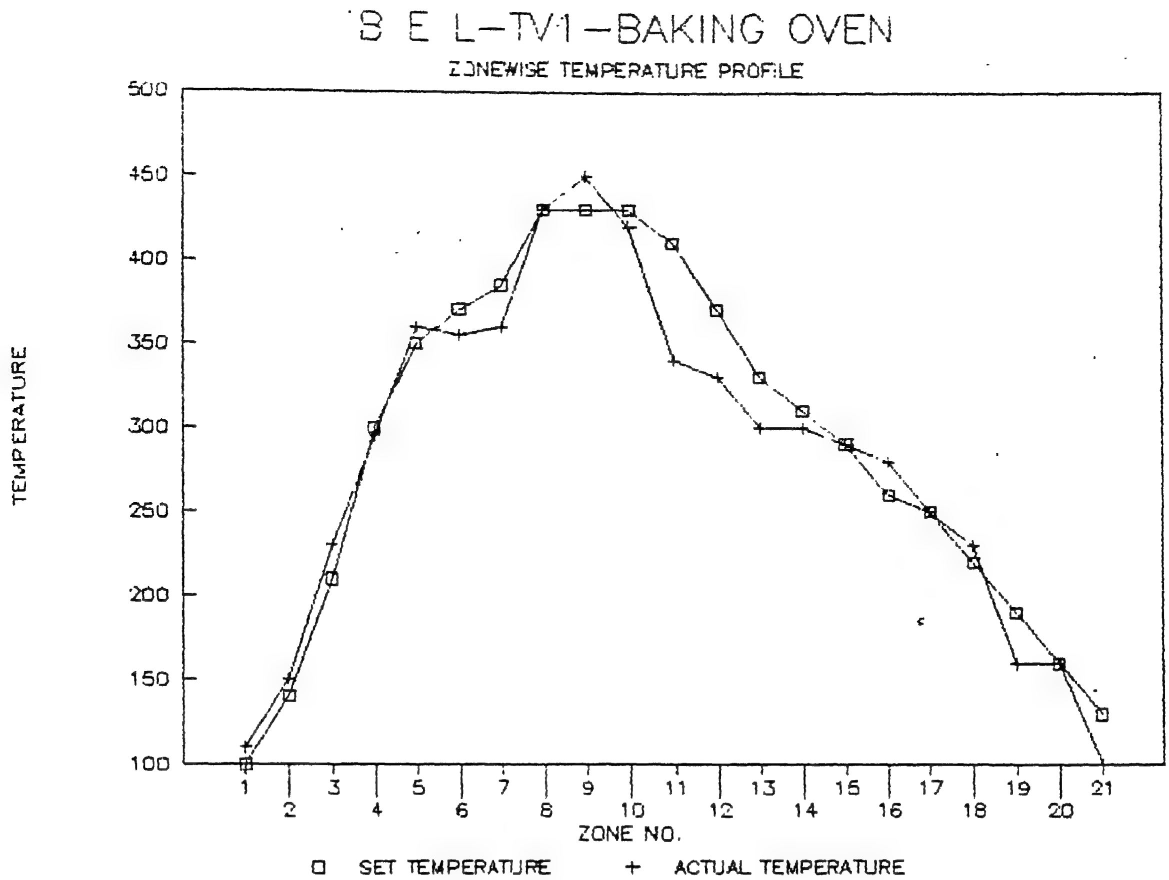
GRAPH 3

BEL-TV PLANT2

ENERGY CONSUMPTION PATTERN

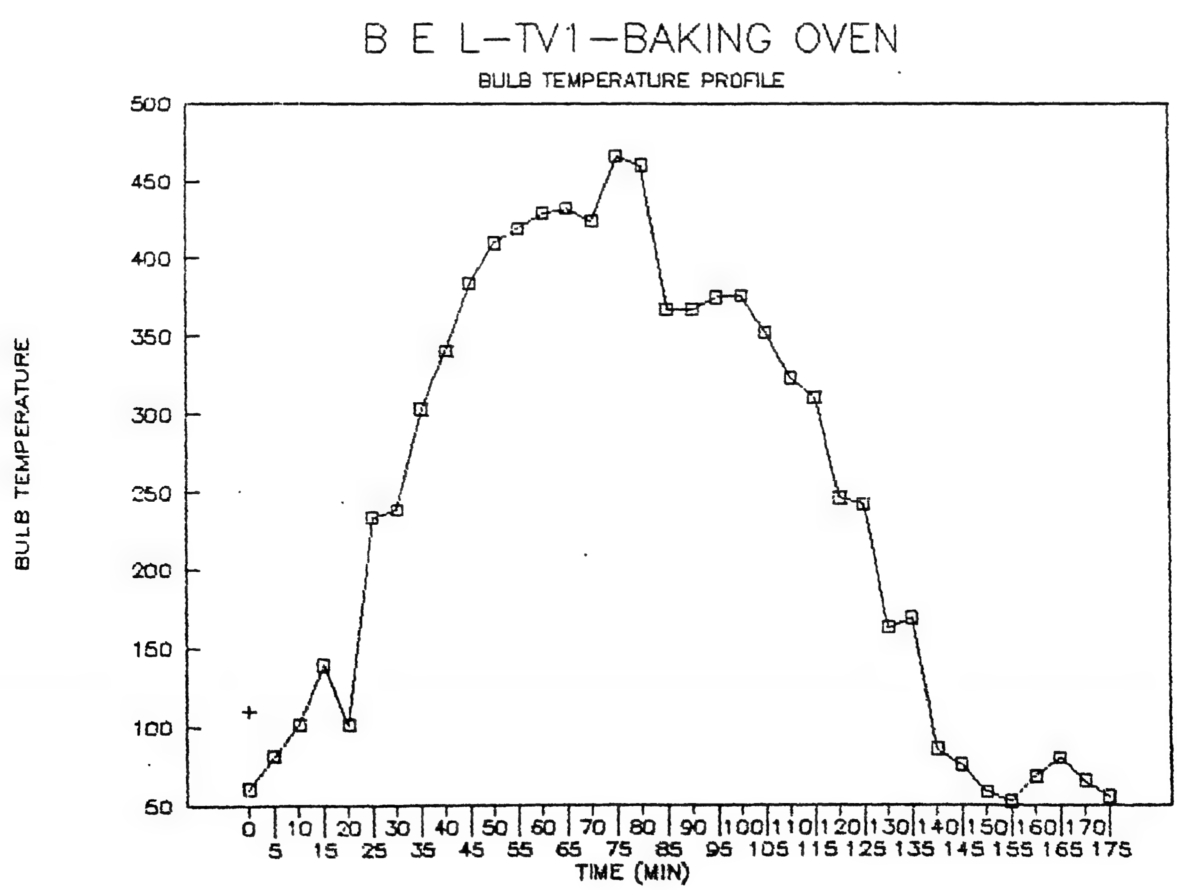


GRAPH-4

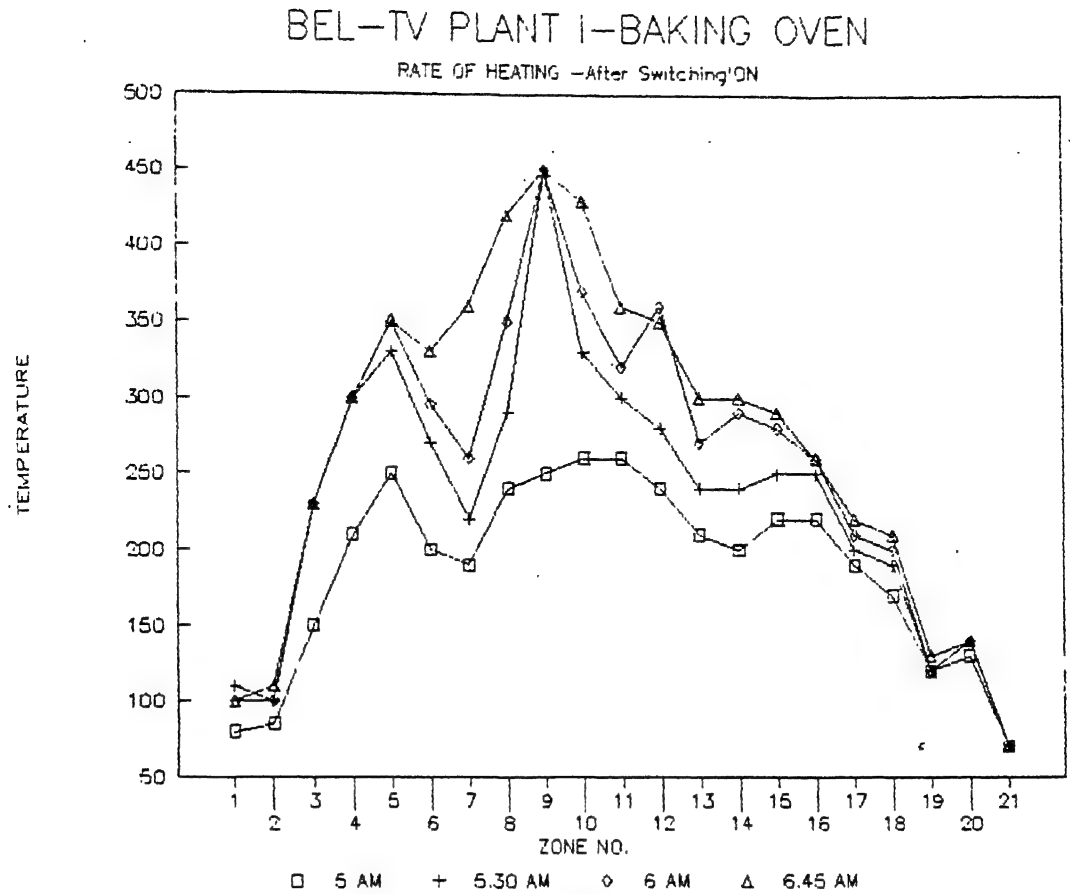


B E L-TV1-BAKING OVEN
ZONEWISE TEMPERATURE PROFILE
TEMPERATURE
500
450
400
350
300
250
200
150
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
ZONE NO.
SET TEMPERATURE
ACTUAL TEMPERATURE

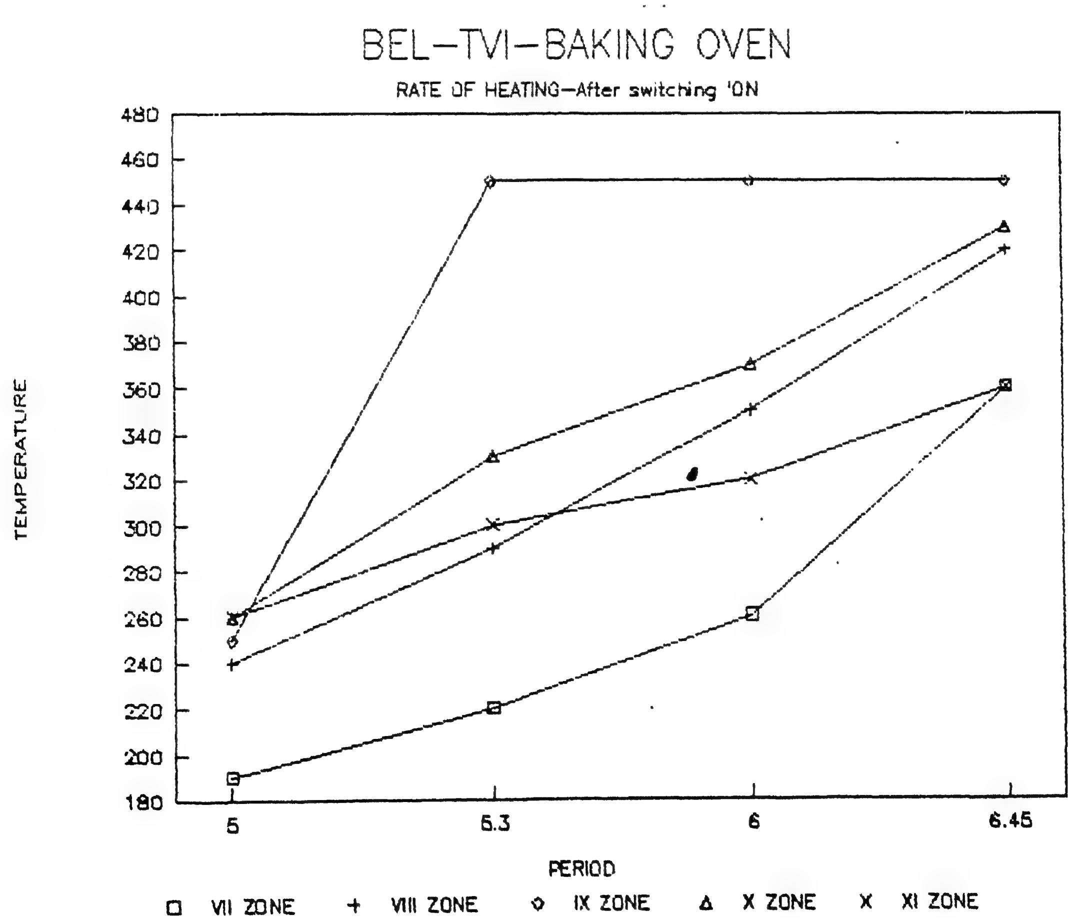
GRAPH-5



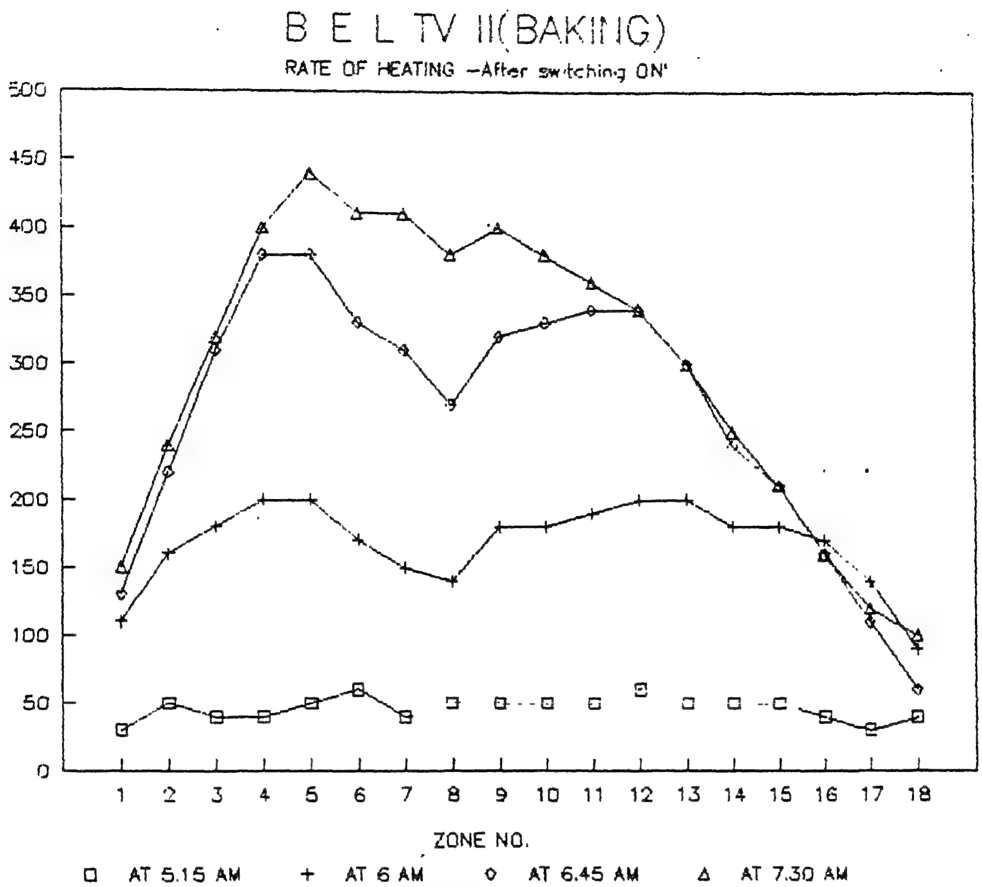
B E L-TV1-BAKING OVEN
BULB TEMPERATURE PROFILE
BULB TEMPERATURE
500
450
400
350
300
250
200
150
100
50
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175
TIME (MIN)



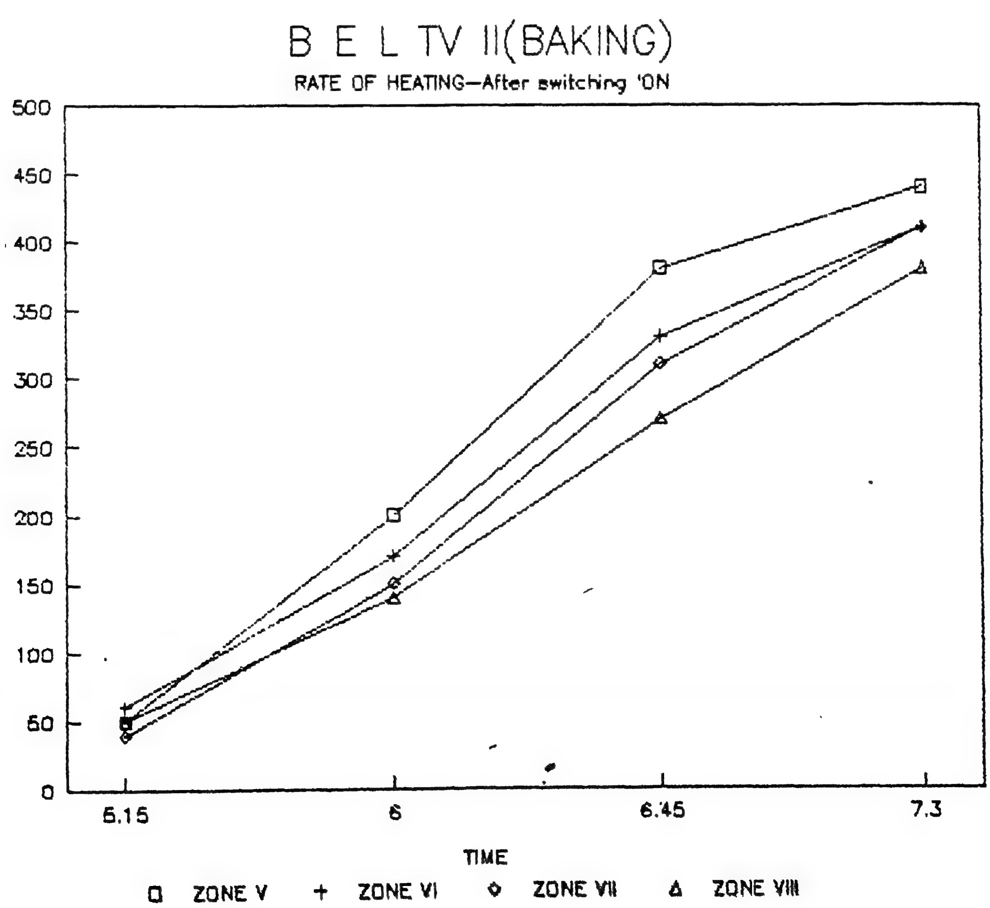
GRAPH-7

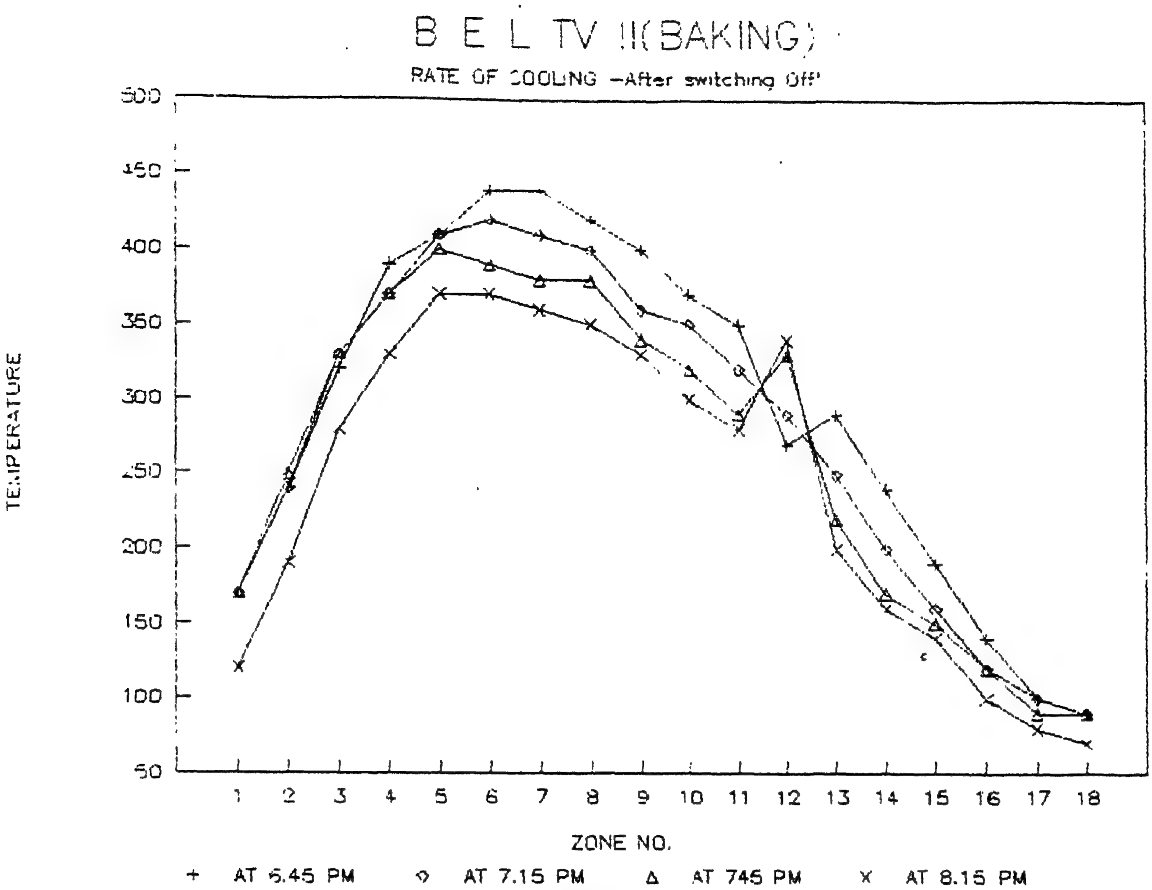


GRAPH-8

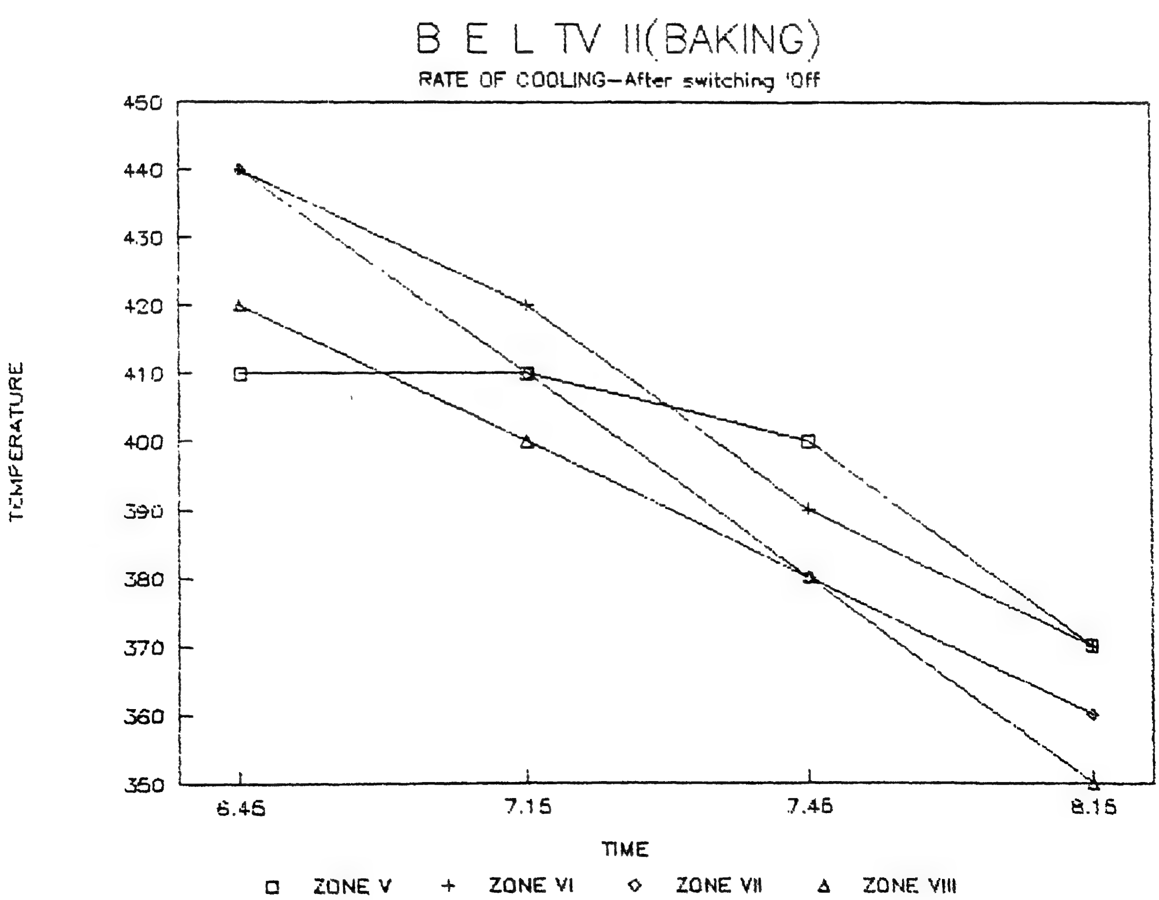

B E L TV II(BAKING)
RATE OF HEATING –After switching ON'
500
450
400
350
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
ZONE NO.
AT 5.15 AM
AT 6 AM
AT 6.45 AM
AT 7.30 AM

GRAPH-9


B E L TV II(BAKING)
RATE OF HEATING–After switching 'ON
500
450
400
350
300
250
200
150
100
50
0
5.15
6
6.45
7.3
TIME
ZONE V
ZONE VI
ZONE VII
ZONE VIII


B E L TV II(BAKING)
RATE OF COOLING –After switching Off'
TEMPERATURE
ZONE NO.
+ AT 6.45 PM
◇ AT 7.15 PM
Δ AT 745 PM
X AT 8.15 PM

GRAPH-11


B E L TV II(BAKING)
RATE OF COOLING–After switching 'Off
TEMPERATURE
TIME
□ ZONE V
+ ZONE VI
◇ ZONE VII
Δ ZONE VIII

SECTION - IV

GAS PLANT

GAS PLANT

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5.0	COLD BOX	5
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7.0	ENERGY MANAGEMENT IN NITROGEN PLANT	6
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GAS PLANT

There are three units manufacturing nitrogen at 160 Nm^3/h. Two of them are supplied by Petrocarbon developments Ltd. Manchestor and the third by BHPV, Visakhapatnam.All the three plants provide nitrogen for consumption in the different divisions of the complex. The energy supplied to the plant is electricity for running the air compressor, electric heater and the chilling unit.

The following recommendations are made after carrying out the comphrehensive energy audit to identify energy conservation opportunities.

1.0 CHILLED AIR INTAKE TO THE AIR COMPRESSOR

It is recommended to chill the air well below the out door temperature by passing it over a refrigerated fluid tube battery, which is the evaporator section of a refrigeration circuit. The practically achievable temperature would be -25°C using an evaporator temperature of around -30°C, and a condensing temperature around 30°C. This aspect will not only reduce the power required for compression by 18 % but also increase the air intake by 22 %. Besides another very essential aspect is that the moisture content of the air (inlet) is much reduced to about negligible. The water vapour is condensed out on to the evaporator's fluid tubes, and almost immediately starts to form ice due to the very cold metal surface. This water vapour does not have to be compressed, saving power.

The water condensing on the surface of the evaporator acts as a quite efficient dust cleaner, trapping most of the dust carried in the air. The reduces the need for high efficiency inlet filters, which can create a pressure drop to be overcome by the compresor, and a much simple filter can be used.

Power used by the refrigeration plant averages around one tenth of the power originally used on the air compressor, and the power savings on the compressors is greater than 30 %. In the present case of the Gas plant about 195 kg/h of air well increase, and the overall net effect on the specific energy consumption would be greater than 40 %. Based on the figures supplied the specific energy consumption will ome down from 1.10 kWh/Nm^3 to 0.77 kWh/Nm^3, which means a savings of 3,80,160 kWh per annum per plant on a conservative basis, whcih amounts to about Rs.5,32,224 per annum per plant.

2.0 HEAT RECOVERY BY PROCESS INTEGRATION

This technique has been applied to the process existing outside the cold box. The latest technologies have exploited this technique and have radically changed the process design. In the present energy survey emphasis is laid only on the minimum investment areas. Detail application of this technique requires considerable time and also major design changes.

The waste gas coming out of the cold box is partly used as braking fluid in the expansion turbine and let out into the atmosphere as a waste gas. About 214 Nm^3/h of this waste gas which is at 8 $^\circ$C is passed through the electric heater of 22 kW and then let into the absorbers for regeneration of the exhausted ones.

It is now recommended to pass the waste gas through an air to air heat exchanger which should be installed before the after cooler of the air compressor. The compressed air presently coming after the second stage compression is at a temperature of 160 $^\circ$C which is to be cooled to as low as 30°C in the after cooler. The waste heat available is now being rejected to the cooling water. The installation of the air to air heat exchanger before the after cooler will now exchange its heat with the waste gases. The echievable temperature of the waste gas after passing through the heat exchanger will be around

160°C. The amount of heat gain will be 10,070 k Cal or 12 kW. This hot gas is now passed through the electric heater where it is further heated to 200°C. The heater output will now be 9275 k Cal or around 11 kW. This electric load is about 50 % of the normal load. The heater operates at 14 hours a day and the savings in this regard will be 50,400 kWh per year or Rs.70,560 per year per unit. For all the three units the annual savings will be Rs.2,11,680. It is expected that the entire investment will be recovered in one year.

3.0 AIR COMPRESSOR AFTER-COOLERS & INTER-COOLERS

The air intake temperature between the stages has significant effect on the energy consumption of the compressor. Decrease in the intake temperature reduces the energy consumption while increase in the intake air temperature increases the energy consumption.

Temperature measurements based on the gauges installed on the system were taken for calculation of the heat exchanger effectiveness. The temperature of the air leaving the interstage cooler was 53 °C. This temperature should be lowered to around 40 °C. This decrease in temperature can be achieved by having clean heat transfer areas free from fouling. The calculations indicate that the compressor will save power by 3 % amounting to about 9600 kWh per annum or Rs.13,440 per annum per unit. totalling to Rs.40,320 for all the three units.

The after-cooler has an outlet temperature of 56°C as against the design outlet temperature of 36°C which 20 °C higher and will increase the cooling load on the refrigeration system and hence increase in power consumption. The present outlet temperature of the chilled air from the Freon evaporator is 10°C as against the design temperature of 5°C. The design heat exchange capacity of the chiller is 10 900 k Cal/h. Based on the sensible heat calculations of the air the

heat load on the evaporator is only 6525 k Cal/h, but the present heat load is 9050 k Cal/h, which is an increase of 2525 k Cal/h or 39 % increase in the heat duty. The increase in the compressor load will be 0.62 kW or 4460 kWh per plant amounting to Rs.18,750 for the three units per annum.

Hence it is suggested that periodic cleaning of the inter cooler and after coolers to prevent fouling of heat transfer areas can save power.

4.0 INSULATION IN THE ABSORBER SYSTEM

The insulation on the electric heater and the piping system of the absorber seem to have detoriated as infered from the measurements taken. Based on the surface temperature measurements heat loss was calculated. The surface temperature on the heater was 94 ^{O}C and the surface temperature of the pipe was 69^{O}C. This represents considerable heat loss. The loss calculated is around 7 kW which represents about 30 % of the heater load. The losses that could be easily saved by improving the insulation will be around would be around 6.25 kW. The savings in this regard would be around 26,250 kWh or Rs.36,750 per annum per unit. For the two Petrocarbon units the amount would be arount Rs.73,500. The BHPV unit insulation is comparitively good.

Absorbers

Surface temperature measurements of absorbers was done to check the insulation for heat leak in and out. The surface temperature during the regeneration of the absorbers was 46 ^{O}C and that of the uninsulated man-hole was 54^{O}C. The calculations indicate that the heat loss works out to be 2.5 kW or 10 500 kWh amounting to about Rs.14,700 per annum per unit. For the two Petrocarbon units the total would be around Rs.29,400. It was also found that the heat transfer by conduction to the legs of the absorbers was considerable. The measurements indicate that the temperature was as high as 93^{O}C. It is suggested to insulate all the legs of the absorbers. Quantification of losses have not been made.

Poor insulation will also cause reverse heat transfer during the normal running cycle. The quantum of heat leak in increases the energy consumption of the unit which is explained in the cold box section. It is therefore suggested to insulate hand-holes, man-holes, and the legs of the absorbers. Quantification in this regard has not been done as the data was not available.

5.0 COLD BOX

The compressed air after being passed through the absorbers is led into the cold bo where its temperature is 8°C as per the design. The air is liquified at a temperature of -169°C by passing it through two fin type plate heat exchangers before entering the distillation column. One of the heat exchangers act as the liquifier for which the cold is produced by passing the oxygen rich air from the top of the distillation column through the liquifier and expanding it in the expansion turbine and again repassing it through the liquifier.

The cold box contains the distillation column, the condensor/evaporator, and the two fin type plate heat exchangers and the portion of the expansion turbine. All these items have a very low temperature the maximum being -146°C and the minimum being -173°C. The cold box is metal cladded and perlite powder is used as an insulation. Since the detailed layout of the different equipment in the cold box is not available heat leakage calculations have not been done. Heat leakage has a significant effect on the energy consumption of the process.

Effect of heat leakage on energy

The standard literature for a similar air seperation plant states that the heat leakage of 100 Btu/lb mole of air increases the energy requirement by about 20 % over that of no leakages. Hence the importace of low temperature insulation in cryogenic process in terms of energy conservation is very high. It is believed that the plant insulation has not been checked since its inception. It is suggested that the insulation in the cold box is checked for its thermal conductivity.

The heat leakage in the cold box occurs mainly by conduction and radiation. The amount of heat transfer through the perlite powder can be reduced by the addition of metalic powders. A mixure containing approximately 40-50 % by weight gives optimum performance. From a safety point of view metallic copper as an opacifier is preferable because of its low heat of combustion in combination with oxygen. This aspect could be discussed with the plant manufacturers and implemented accordingly. This will reduce the heat leakage by another 50 % and is definitely worthwhile exploring.

6.0 EXPANSION TURBINE

The expansion turbine is the heart of the cold box which produces the cold for liquifying the air in the fin type plate heat exchangers. The adiabatic efficiency and the cold produced were calculated based on the pressures and temperatures indicated by the gauges installed in the units. The calculations indicate that the adiabatic efficiency is 70.18 % as against the design efficiency of 70 % and the cold produced is 3744 k Cal/h. The expansion turbine is working satisfactorily true to the specifications but the cold produced is less than that indicated in the design parameters. Standard literature states that an expanded efficiency of 40 % increases the energy requirement by about 20 % over that with 100 % efficiency.

7.0 ENERGY MANAGEMENT IN NITROGEN PLANT

The plant maintains elaborate energy related records and also the break up of consumption of the different gases supplied to various units in the complex. The plant also has energy meters installed on individual air compressor motors. No records of energy meter readings are maintained. The present energy record is based on the running hours of the machines and hence the specific energy consumption is constant throughout the year. Since the production rates will vary due to

seasonal factors, for the same amount of power expended the specific energy consumption will also vary and can easily be 5 % higher in the summer months when compared to the winter months. It is therefore suggested that daily actual energy meter readings are used for energy consumption recordings and specific energy calculations.

Consideration for long term measure

There has been tremendous technological development in cryogenics because of rapid growth in its applications specifically in the defence and space technology. The present trends are to go for centrifugal compressors depending upon the economies of scale. It is suggested to consider the latest technologies and to replace the existing three plants with a single large unit keeping in view the future.(It was felt from the discussions that the complex is thinking of going for the fourth unit of a similar capacity and technology.) Since the plant requires both oxygen and nitrogen for internal consumption it is suggested to consider the manufacture of both nitrogen and oxygen in the new plant, the energy consumed in seperating both oxygen and nitrogen will be almost same as in seperation of nitrogen alone.

Presently oxygen is produced by electrolysis process of water. This can be eliminated if the oxygen is produced from air while producing nitrogen and at the same time scarce commodities like water and power could be saved. The present system of buying hydrogen can be continued as it is highly economical.

SUMMARY OF RECOMMENDATIONS:

A) **House keeping measures**

Recording of daily kWh readings of the energy meter of the air compressor. This is to arrive at the actual specific energy consumption of the three plants individually.

To chalk out the preventive maintenance schedule for all essential items for each of the plants, like cleaning of heat exchangers, cleaning of airfilters, instrument calibration etc,.

Maintain hourly log book which contains essential parameters like pressures, temperatures, flow rates etc,. This will be a valuable record for analysis and feed back.

Eliminate leakages in valves and joints on a daily basis.

(B) **Recommendation with minor investments**

Replace detoriated insulation after the freon evaporator onwards till the cold box.

To check with the plant manufacturer and to add 40 -50 % by weight of copper powder to perlite insulation in the cold box. This will reduce the thermal conductivity by 50 %.

To modify the piping and installation of an air to air heat exchanger before the after cooler for preheating the waste gas going to the absorber through the electric heater.

Installation of air chilling plant such that the air intake temperatures are reduced to -25°C.

C) **Recommendation with major investment**

To consider one large plant to manufacture both oxygen and nitrogen with the latest technologies instead of the existing smaller ones.

SECTION - V

IC PLANT

I C PLANT

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I C PLANT

REFRIGERATION AND AIR CONDITIONING

FACILITY DESCRIPTION

The refrigeration system of the plant consists of eight units. Each unit has two compressors, two condensers and a single flooded type evaporaters. The capacity of each unit is 200 tons of refrigeration (TR). Each of the unit has the capacity of operating two compressors in parallel or individually. The entire system, has been designed and installed by voltas. The compressors model used is No.651526. Each of these compressors has facilities to operate between 45 to 100% of full load capacity. The compressor is of direct derive model operatng at 1450 RPM, using R22, as the medium of refrigeration The compressors are driven by 125 HP motors of NGEF make.

The cooling water to the condensers is cooled in the overhead cooling tower, which is designed to handle 309 litres/sec with the cooling water outlet temperature 28.9°C at ambient air wet bulb temperature of 25.6°C. The fans on the cooling tower are operated with 25HP motors each. There are 3 nos. of cooling water pumps of centrifugal type out of which two are operated. The pumps are driven by 50 HP motor.

The refrigeration system has the capacity to chill water at 8.7 lac liters/hour to the required temperature of 5.6°C when the inlet temperature is at 11.1°C. The chilled water is supplied to the different air handling units of various capacities [illegible]. There are 3 nos. of chilled water pumps of critifugal type out of which only two are always in operation. The capacities of each of the pumps is 53 litres/sec. The entire chilled water has been effectively insulated. Each of the pump is driven by a 30 HP motor.

The plant was studied in detail for about 10 days and various measures were taken in the various refrigeration, air handling and in the rooms including the clean air rooms. The measurements were also taken in the cooling towers.

MEASUREMENTS IN THE REFRIGERATION SYSTEM

At the time of taking the measurements of the 16 Nos. compressors only 5 to 8 nos. were run depending upon the load requirements. Readings of the temperatures and pressures of the ring compressorss were only taken.

CHILLERS:

The chillers are of flooded type which two level controlling valves operating in parallel. In the present system the refrigerant enters the chiller after it has been chilled by the gases going to the compressors from chiller.

Table 2 gives the inlet and outlet temperatures and inlet and outlet pressures of the various chillers in operation. Pressure readings were not available as pressure gauges were not installed on the chilled water side. The chilled water header temperatures was maintained at 9.7°C on the day the measurements were taken. The maximum temperature drop of the chilled water was 4°C and minimum temperature drop was 0.55°C, which were for chiller no.3 and chiller no.7 respectively. (Please refer to table no.3 for causes and the efffect of poor evaporation effectiveness).

In the case of chiller no.3 there has been increase of about 4% in the cooling duly and 21% increase in COP. which indicates that there is power savings whereas in compressor no.7, the chiller effectiveness is almost reduced to 8.5%, of its capacity and the loss in the COP is about 85%. Which means that the losses amount to about 8,83,280 Kwh per annum amounting to Rs.12,33,792. These calculations are done for the best performing chiller and the worst performing chiller. It is suggested to take appropriate action in this regard after referring to table no.3.

Realistic figures of saving can be arrived at only by taking readings of all the chiller. However, if the present indications as per chiller no.7 and chiller no.3 are to be considered, scope for savings will be considerable. Hence immediate correction action should be taken.

Readings taken for chillers when the compressors are underloaded on only when one compresser is being operated, even though it is at its full capacity is likely to give erroneous readings because the chiller is actually designed for double the cooling capacities ie., for two compressors operating in parallel.

Table 12 gives the chilled water pump motor readings.

COMPRESSORS

The purpose of the compressor in a refrigeration system is to draw refrigerant vapour from the evaporater, therefore lowering the pressure and causing the liquid refrigerant to boil extracting heat from the load at the desired temperature. The pressure of the vapour must then be raised by the compressor to a level where the vapour can be condensed by the available cooling medium.

The designed suction saturated temperature is $0^{o}C$ and the saturated discharge temperature is $40^{o}C$. The thermodynamic properties of R-22 at these temperatures are shown in Table -5. The actual operational details of the various compressors is shown in table -6. This shows that the compression ratio is almost steady at the various capacities and the compressors are operating close to the design conditions. Any increase in the compression ratio indicates increase in capacity reduction and increase in power consumption. The discharge pressure for compressors no.6 should be checked , as it discharge pressure is considerably higher.

Compressor discharge temperature was observed to be higher than 40C. Random surface temperatures taken indicated around 45^{o}C, which means that the actual refrigerant temperature is much higher. However, it is suggested to make provisions to measure the discharge temperature so that actual quantifications of the increased power consumption could be calculated.

The efficiency of the compressor is affected by the performance of the valves, the valve design being optimised for the refrigerant and pressure ratio used. Operating a compressor with valves designed for low temperatures opeations at high temperature could result in a 5 - 10% reduction in cooling duty and a 20% reduction in compressor efficiency. The should be checked with the actual measurements.

However the following aspects should be considered from energy angle :

1. Sub cooling of the liquid before entering the expansion valve or throlling device reduces the H.P.required per ton, this is presently being done. However, the actual effectiveness of the heat exchanger should be checked by taking the required temperature measurements.

2. Discharge pressure increase or increase in compression ratio with suction pressure steady decreases the capacity of the compressor and the power requirement goes up. It is suggested have to install calibrated gauges on the compressor discharge.

3. As suction pressure comes down, the compressor capacity drops and hence increase in the HP per of TR.

4. Superheating of suction gas increases the HP per ton, due to drop in compressor capacity.

COMPRESSOR CAPACITY REDUCTION

Capacity reduction by unloading the cylinders is presently being done. Which is fairly efficiency way of operating at reduced loads, a compressor with half the cylinders unloaded will consume about 53% of the power of a fully loaded machine over the same pressure ratio.

A more superior method of part load is now available. Using variable speed motor drives which allow fully variable capacity control within the speed and pressure limits of the compressors. Typically, turn down to 40% of full load is possible without cylinders unloading.

Table - 7 gives the motor readings of the various compressors operating at different capacities. It can also be observed that none of the compressors is operating at full load. The most economic way to run the plant would be to operate the required number of compressors to full load duty so that they operate at almost full load COP. This should be done by the plant personnel , who have the feel for the process. **The effect of this is shown in Fig.2.**

CONDENSERS

Shell and tube condensers are used for condensing the refrigerant carrying out of the compressors. There are two condensers one for each compressor. The design parameters are a rise of 4.5°C in the temperature of the cooling water , with a maximum head loss of 6.09 metres of water or 0.609 Kg/cm2 pressure drop across the exchanger.

Table -8 gives the details of Inlet/outlet pressures and tempeatures of the condensers in operation. The maximum temperature rise got was 3.3°C for the compressor 8 and minimum temperature rise was 0.5°C for compressor 7 and compressor 6.

The pressure drops across the condensers were very much on the higher side with the lowest occuring for compressor 3 and highest for compressor 8. However, both the pressure drops are greater than the designed pressure drop of 0.6 Kg/cm2.

The low temperature rise and high presure drop indicate that the condensers are choked and due to fouling and needs immediate attention. This is causing poor heat transfer and the maximum heat transferred is about 50% of the design. This will lead to higher discharge temperature from the condensers of the refrigerant and will also over load the heat exchanger. The degree of super heat is likely to be high of the refrigerant going to the suction of the compressor thereby reducing the overall refrigerant effect and increasing the power consumption. The actual increase in power can be arrived at by measuring temperatures. Inthis case, a loss of 20% in the COP could be vey low (Please refer table 3 for details and effect on the COP).

To get good heat transfers, the water velocity should be as high as possible, consistent with reasonable pumping power and freedom from errosion. A water temperature rise of 5°C (4.5°C in the present case) and a tempeature approach of 5°C between water and exit temperatures and condensing temperature are good operational practices.

COOLING TOWER

For the minimum condensing temperature, the power consumed by the compressor will be the lowest, hence the cooling water temperature should be maintained at the lowest possible.

In cooling towers, the cooling effect is achieved by evaporating some of the water in air, the latent heat required comes from the remaining water which is consequently cooled. The efficiency of the cooling towers depends on obtaining a thorough mixing of the air and water streams, and a poor efficiencies are almost always caused by blockages reducing air or water flows.

All the problems relating to blockages and obstructions are due to mineral/or algae growth. Mineral deposition is usally controlled by water treatment and periodic or continuous blow down which limits the concentration of minerals in water. Algae growth is controlled by dosing the water with biocides.

Table -9 gives the details of the cooling tower temperatures and the wet bulb and dry bulb temperatures taken on the day.

The cooling tower is designed to operate with an approach of 4.4°C when the cooling water entering is at 33.3°C and leaving is at 28.9°C at a wet bulb temperature of 25.6°C. The cooling tower has 3 nos. of fans, one for each cell. The fans are driven by 25 HP motors. However, at the time of taking the readings, only one fan was running. Presently a system of manually switching off of the fans when the weather conditions are permissible and also when the cooling water load on the cooling tower is low. Fig.No.1 shows a typical automatic control system for controlling the operation of cooling tower. The temperatures sensers the necessity for cooling and controls the by-pass valve and fan in sequence. If the cooling water is below the control temperature, for instance, when the compressor load is low or switchoff, the by pass valve opens and the cooling tower fan is switched off.

The outdoor data normally used in Bangalore, based on the meterological data is shown in Table - 10. This data can be made use of to obtain the necessary benefits of conserving energy. Two schemes are suggested which will bring about considerable energy savings.

a. To run the cooling tower and obtain the chilled water required during winter. Entire compressor load can be done away with when this is to be done. Based on the data supplied, the present practice is to run only one compressor or at the most two. If this measure is adopted, the entire compressor power can be saved amounting to Rs.2.8 lacs per month for the period of operation in winter.

b. The second method is to carry out cooling in two stages, first in the cooling tower and then in the chillers. Fig. 3 and 4 dipict the two scheme. With the result the compressor power will be reduced by 50 % during the season when the wet bulb temperature makes it possible for such an operation.

Table - 11 gives the cooling water pump/condenser water pump motors readings.

LOSS OF CONDENSER EFFICIENCY DUE TO NON-CONDENSIBLE GASES

Air and others non- condensible gases can get into refrigeration system in several ways. The most common reason is insufficient evacuation of vessels prior to initial charging or after maintenance. In systems which operate always on occassionally with sub - atmospheric pressures in the evaporator, leaks will be inward rather than outward and large quantities of air can get in over a period of time. In any system there will be a very slow break down of the refrigerant and this too rsults in a buildup of non - condensible gases.

The build - up of air and other non - condensible gases result in high condensing temperatures and high apparant liquid sub - cooling in the condenser and their effect on operating efficiency can be considerable.

This test was carried out in unit 7 by isolating the condenser after pressurising with the refrigerant. The test revealed that the non condensible of about 30%. For actual quantifications, this test should be carried out for all the units. The increase in compression power is around 10% . For this particular case the energy saved by purging the condenser would be Rs.56,035 on reduced load operations. On full load operations the savings will be still higher.

POWER CONSUMPTION BY THE VARIOUS AIR HANDLING UNITS:

The motor readings of the various air handling units given in table -13. Majority of the air handling units have energy meters and provision should be made to take daily readings of the power consumption so that monitoring exercise could be carried out . A centralised system on to a computers could be used.

Automatic guide vane controllers for regulating the air intake in many of the air handling unit were found to be out of order and should be attended to immediately. Quantification in this regard could not be carried out but considerable energy savings could be brought about.

INSTRUMENTATION AND RECORDS TO BE MAINTAINED:

Figure 5 gives the detail instrumentations required. These should be recorded in plant log sheets. Plant log sheets provide an effective way of gathering data on plant performance and they are of use only if, the data recorded is accurate, the information is intelligently analyzed, and any problems identified and followed up. A sample log sheet is depicted in fig 6 and fig7 .

The plant presently maintains no log sheet, hence performance monitoring and measurements not possible. Besides, these performance details should be regularly compared with the design and/or commissioning details. Records of the commissioning data are not available.

AUTOMATIC MONITORING:

For a large complex unit like that of IC unit, automatic monitoring with the help of micro electronic based monitoring and data logging system should be used. The most widespread application has been to incorporate the refrigeration system into the main process control system.

IC PLANT

AIR HANDLING SYSTEM

1.0 INTRODUCTION:

IC Plant has the installed airconditioning capacity of 1600 tons. Depending on the seasonal variation 500-800 tons of capacity is used. The total area of air conditioning accounts for 5350 Sq.mts, while the total area of ventillation comes to 3650 Sq.mts.

There are 20 Air Handling Units (AHUs)supplying cold air to various departments. AHU 1 to 5 supply air through ducts while AHU 6 to 16 supply air through top plenums and the air returns back in the bottom plenum. AHU 6 to 16 are designed for laminar flow of air to maintain clean room effect of class 10,000. The air change rates in these departments vary around 300 air changes per hour.

During the period of study AHU 8,11,14 were under modifications. AHU 17 & 18 are used to supply the fresh air requirement of AHU 1 to 10 and AHU 19 & 20 are used to supply the fresh air requiremnt of AHU 11 to 16. AHU 14,15 & 16 are equipped with KATHABAR system as all the yellow room departments are designed to maintain air temperature, humidity and bacteria as required.

The department-wise analysis has been made after collecting the necessary data from the plant personnel and measuring necessary parameters using Temperature indicator, RH Indicator, Anemometer, Thermograph etc.

The observations, measurements and recommendations department-wise are discussed as follows

OBSERVATIONS, MEASUREMENTS & RECOMMENDATIONS:

1. LCD:

AHU 1 supplies the chilled air to this department through a duct. The measurements taken at AHU1 are as follows:

Room temperature = 24.9°C.
Temperature before coil = 24.9°C.
Temperature after coil = 22°C.
Amount of air handled = 8895 cfm. against the designed value of 10700 cfm.

It was observed during the study that the room temperature and Relative Humidity are maintained at 22°C and 34 % respectively which are very low compared to the desired levels of 25.6°C and 50% of RH, indicating that the rooms are over cooled. It is recommended to raise the room temperature to the desired levels to reduce the load on the refrigeration system.

2. TO 92

The supply air to this department is supplied by AHU 2. The measurements made in the rooms where the unit is situated indicate that the air temperature before and after coil is 23.5 °C and 20°C respectively. The amount of air handled by the unit is around 8338 cfm against a design value of 10700 cfm.

The room temperature was observed to be at 22°C and RH ar 48.7% against a desired level of 25.6°C and RH of 50 %. This shows that the room is over cooled by 3.6°C although the relative humidity seems to be all right, thereby over loading the system.

It is recommended to raise the temperatures of the department to the desired level. It is suggested to clean the filters periodically as the velocity of the air through the filters varies from 0.87 m/sec at some filters to 1.76 m/sec.

3. IC MOULDING:

The supply air to this department is supplied by AHU 3. Measurements show that the temperature before and after the coil was 23.5°C and 18°C respectively. The amount of air handled by this unit was around 9810 cfm against a designed value of 10650 cfm which is very good.

During the discussion with the plant personnel the study team was told that this department has only ventillation and no air conditioning. But it can be seen from the readings that the temperature after the coil is around 18°C which is sufficient to keep the room temperature at 25°C.

4. TO 220:

The chilled air to this department is supplied by AHU 4. Measurements show that the room temperature where the unit is installed was around 22°C and RH at 56.4%. The amount of air handled was around 12114 cfm agianst a design value of 11850 cfm.

It was observed in the AHU room that one filter was completely found removed and the air is being short circuited. The effect of this can be seen in over loading the system as the amount of air handled was more than the designed value.

The temperature in the department was 21°C and RH at 45.7% against a design value of 25.6°C and 50% RH. It was also observed that for this department there are 18 supply air ducts and there are practically no return air ducts at all.

It is recommended to raise the temperature of the supply air to the desired level as presently the department is being over cooled by 4.6°C.

5. H M C:

The supply air to this department is provided by AHU 5. The room in which this unit is installed was at a temperature of 25.9°C and RH of 58 %. The amount of air handled by this unit is only 14500 cfm against a design value of 22900 cfm.

It was observed that there were no filters at both ends of the filter unit and almost the entire quantity of air was observed to be going through these openings. Over all the entire filter unit and the coil fin system needs to cleand as the entire fin system was found clogged limiting the air flow across.

It was observed during the study that there are 3 big ovens and number of heaters located with in the air conditioned area. The total heating load in the department was estimated to be 300 kW against a designed load of 80 kW. With the result the temperature inside the department was around 28°C against a design value of 25.6°C which 2.4°C more than the desired level.

It is strongly recommended either to isolate all the heating surfaces or to insulate them effectively to reduce the heating load on the refrigeration system.

6. **PD ASSEMBLY:**

AHU 6 supplies the chilled air to this department. The temperatures before and after the cooling coil were 24°C and 17°C respectively.

It was observed that the entire fin system of the AHU 6 was ~~fully~~ completely choked, with the result the temperature of the department was around 27°C against a desired value of 25.6°C.

It is recommended to clean the entire fin system & filter unit immediately to get the effective heat transfer to the supply air.

It was also observed that there are Hydrogen & Nitrogen burners located inside the air conditioned space thereby heating the entire zone. It is suggested to isolate the firing zone with some duct arrangement to avoid the direct contact of fire with room air.

It was observed that there are many furnaces with inside temperature of around 1300 ^{o}C which is sometime or the other in direct contact with the room ambient. The surface temperature of the thermofurnace door was measured to be more than 100 ^{o}C and the exhaust duct of the other furnaces were at a temperature of 60^{o}C for the first 2,3 metres of the length. With this effect the room air temperature near that zone was around 28^{o}C and RH of 42%.

It is strongly recommended to effectively insulate all the heating surfaces to reduce the load on the air conditioning system and improve the coefficient of performance.

9. **IC DIFFUSION:**

The supply air to this department is handled by AHU 10. The temperature of air before and after coil was 13^{o}C and 9^{o}C respectively. The amount of air handled by this unit was around 70000 cfm against a design value of 93000 cfm.

The department has an average temperature of 22^{o}C and RH of 50.6^{o}C which indicates that the department is being cooled beyond the desired levels. Like PD diffusion department this department also has several furnaces & ovens installed with surface temperatures at some points around 80^{o}C. The exhaust duct of the furnaces was left uninsulated.

It is strongly suggested to insulate all the hot surfaces and reduce the load on the system.

10. **WHITE ROOMS(PD & IC):**

AHU 12 & 13 handle the supply air requirement of PD and IC white rooms respectively. The temperature of air before and after the coil in both the units was around 23^{o}C and 17^{o}C respectively. The amount of air handled was 13500 cfm by AHU 12 and 12000 cfm by AHU 13 against a design value of 15750 cfm.

The department temperature was observed to be at 26 ^{o}C. Some heating equipment was found in this department also but the surface temperatures were in the reasonable limits.

11. YELLOW ROOMS(PD & IC):

The supply air to these two departments are handled by AHU 15 & 16. These two departments utilise the KATHABAR system also to maintain air temperature, humidity and bacteria as required. The amount of air handled by these units was around 13000 cfm each against a designed value of 15750 cfm.

The temperature of the department was maintained at 25°C and at RH of 42.6%.

TABLE - 3

SOME OF THE COMMON FAULTS ON REFRIGERATION SYSTEM

Major symptom	Other Symptoms	Fault	Solution	Operational Cost penalty
Low cooling duty compared with compressor curves	Bubbles in liquid line and low or zero sub cooling from	System undercharged LP float or TEV system	Add refrigerant to correct level	Upto 25% or more redn. in duty and COP
	On HP float systems	HP float valve stuck open bypassed, gas gas passing	Determine why bypass valve was opened initially. Correct fault and close by pass valve.	Upto 50% redn. in duty and COP.
	High actual compressor discharge temp & low compressor absorbed	Broken or obstructed reciprocating compressor	Repair valve and identify and rectify cause of	Loss of duty in proportion to cylinders affected.
Poor evaporator effectiveness	Low evaporating pressure high water/air side pressure drop	Fouling of air/water side of evaporator	Clean evaporator and locate and cure source of fouling	Upto 15% loss in COP 25% loss of cooling duty
	Low evaporating pressure high apparent super heat.	Blocked suction strainer	clean suction strainer. Identify and rectify source of blockage	Up to 15% loss in COP 25% loss of cooling duty
	Loss of oil from compressor crankcase	oil accumulation in flooded evaporator	Remove excess oil, install effective oil drain or recttification system	Upto 30% reduction in COP
	Loss of oil from compressor crankcase	Poor oil return from expansion valve system	Re-design suction side pipe work	Upto 25% reduction in COP

	All systems: possible high liquid line subcooling, high suction superheat	Obstruction in liquid line	Locate and clear obstruction. Identify cause and rectify	Upto 25% reduction in duty and COP
Poor condenser effectiveness	High condensing temperature, high liquid sub cooling	Very high over charge of LP float or TEV system	Remove excess charge	Upto 10% loss of duty, 15% reduction in COP
	High condensing high liquid subcooling	Air or non condensible gas in system	Purge non-condensible gas from condenser	Upto 10% loss in COP
	High water/air side pressure drop	Fouling of air/water side of condenser	Clean condenser and locate and cure source of fouling	Upto 25% loss in COP, 10% loss in duty
Low Suction Superheat	LP float and TEV: possible low compressor discharge temperature	Incorrect or faulty expansion device control	Identify and rectify fault	Upto 15% reduction in duty. Potential compressor failure due to liquid carry over.
High Suction Superheat	HP float: low liquid level in evaporator	System under charged	Add refrigerant to correct level	Upto 10% loss of duty, 71/2% reduction in COP
Low oil Differential pressure (Halocarbons)	Foaming of oil in crankcase particularly on start-up.	Refrigerant dissolved in crankcase oil in halocarbon systems due to crank case heater failure or liquid refrigerant in suction gas	Check operation of crankcase heater oil temperature should be 50-60deg. If heater OK check expansion device.	Potential compressor failure

TABLE 2

CHILLER PERFORMANCE

CHILLER NO.	TEMPERATURES INLET Deg.C	OUTLET Deg.C	REMARKS
3	9	5	insulation damaged
4	6	4.5	
6	NA	NA	
7	6.6	7.2	
8	9	6	

Note: Pressure readings were not available

TABLE 5

THERMODYNAMIC PROPERTIES OF R22

PARAMETERS	TEMP 0 C	TEMP 40 C
Pressure(psig)	57.8	209.9
Density, Liquid (lb/cu.ft)	80.21	70.74
Vapour	1.326	4.22
Heat content (btu/lb)		
Liquid	19.32	42.32
Vapour	108.33	113.16
Latent	89.01	70.84

TABLE 6

COMPRESSOR NO.	SUCTION PR. (psig)	DISCHARGE PR. (psig)	LOAD CONDITION Amps
2A	67.5	202	125
3	67.5	NA	-
4A	60	NA	130
6A	60	NA	-
6	60	260	130
7	60	210	140
7A	57	206	150
8	70	190	-

TABLE 4

CALCULATION OF C O P:

Carnot COP $= T_e/(T_c-T_e)$

$= 273/(313-273)$

$= 6.825$

Actual COP (Chiller plant efficiency)

= Energy removed by evaporation devided by the energy supplied to the compressor

$= (600 * 1000)/(100 * 860 * 2)$

$= 3.48$

TABLE 7

COMPRESSOR MOTOR READINGS

COMPRESSOR	kW	kVA	P.F	AMPS	VOLTS
2A	63.0	81.0	0.81	120.2	388
3	60.3	75.3	0.80	112.4	388
6A	58.8	73.2	0.80	111.3	380
6	58.8	71.4	0.80	109.2	380
7A	55.6	69.6	0.79	106.5	380
8	75.9	90.6	0.84	137.0	381

TABLE 8

CONDENSOR OPERATIONAL PARAMETERS

CONDENSOR NO.	COOLING WATER TEMPERATURE(^{O}C) INLET	OUTLET	COOLING WATER PRESSURE KG/CM^2(G) INLET	OUTLET
2A	NA	NA	3.5	2.78
3	29	NA	3.5	NA
4A	29	28	3.5	2.6
6	29	27	3.5	NA
7	29	29.5	3.6	2.4
8	29	32.	3.5	2.0

TABLE 9

COOLING TOWER TEMPERATURES

Cooling water inlet temperature	=	30 ^{o}C.
Cooling water outlet temperature	=	27 ^{o}C
Wet bulb temperature (ata)	=	22 ^{o}C
Dry bulb temperature (ata)	=	32 ^{o}C.

TABLE 10

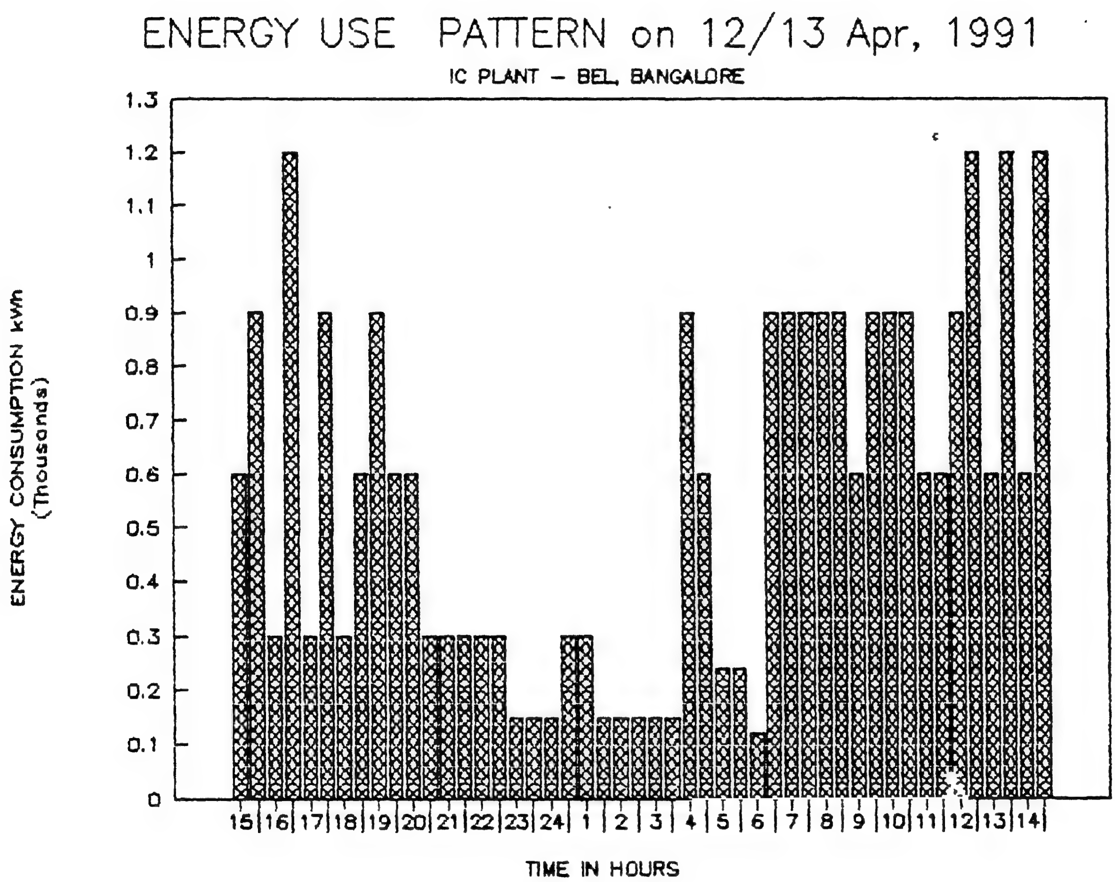
BANGALORE METEOROLOGICAL DATA

SUMMER			MONSOON			WINTER		
DB ^{o}C	WB	RH %	DB ^{o}C	WB	RH %	DB ^{o}C	WB	RH %
35.6	25.6	45	27.8	25.6	82	14.4	12.2	78

TABLE 12

PERFORMANCE OF MOTORS

MOTOR DETAILS	KW	KVA	P.F	AMPS	VOLTS
Chilled water					
pump 2	51.66	59.7	0.87	89.6	382
pump 3	54.81	61.5	0.88	93.2	382
Condensor water					
pump 2	56.01	66.0	0.84	97.4	393
pump 3	56.34	65.7	0.85	97.6	393
AIR HANDLING UNITS:					
9A	41.25	55.8	0.75	80.3	397
10B	28.83	46.3	0.61	66.9	397
12B	12.78	16.6	0.83	24.4	397
15B	15.45	12.9	0.72	18.9	397
13A	8.28	11.3	0.74	16.7	397
16A	6.51	17.2	0.73	25.5	397
VF1	21.75	25.9	0.78	29.5	374
17	15.57	20.1	0.78	29.0	374
18	13.11	16.2	0.76	23.9	374



ENERGY USE PATTERN on 12/13 Apr, 1991
IC PLANT – BEL, BANGALORE
ENERGY CONSUMPTION kWh
(Thousands)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
15 16 17 18 19 20 21 22 23 24 1 2 3 4 5 6 7 8 9 10 11 12 13 14
TIME IN HOURS

IC PLANT - BEL

MONTH	1988-89 PRODUCTION Lacs	ELECTRICITY kWh	1989-90 PRODUCTION Lacs	ELECTRICITY kWh	1990-91 PRODUCTION Lacs	ELECTRICITY kWh
Apr	57.73	970891	64.01	950393	60.68	932099
May	51.94	1017910	52.15	982628	68.20	986428
Jun	58.68	930585	70.48	950745	63.00	883073
Jul	54.10	958440	74.82	911627	144.38	871019
Aug	52.19	1036352	63.83	942550	60.49	721976
Sep	64.56	982013	53.75	967680	92.92	816508
Oct	52.04	975494	55.01	856006	87.24	754874
Nov	58.21	906152	42.16	763910	86.07	821298
Dec	79.80	1011692	108.48	800980	118.93	830963
Jan	76.33	880552	121.74	788418	66.92	729083
Feb	68.17	830901	102.51	766988	51.51	661553
Mar	97.18	1033329	176.62	925638	86.01	831093
TOTAL	770.93	11534311	985.56	10607563	986.35	9839967

IC BUILDING

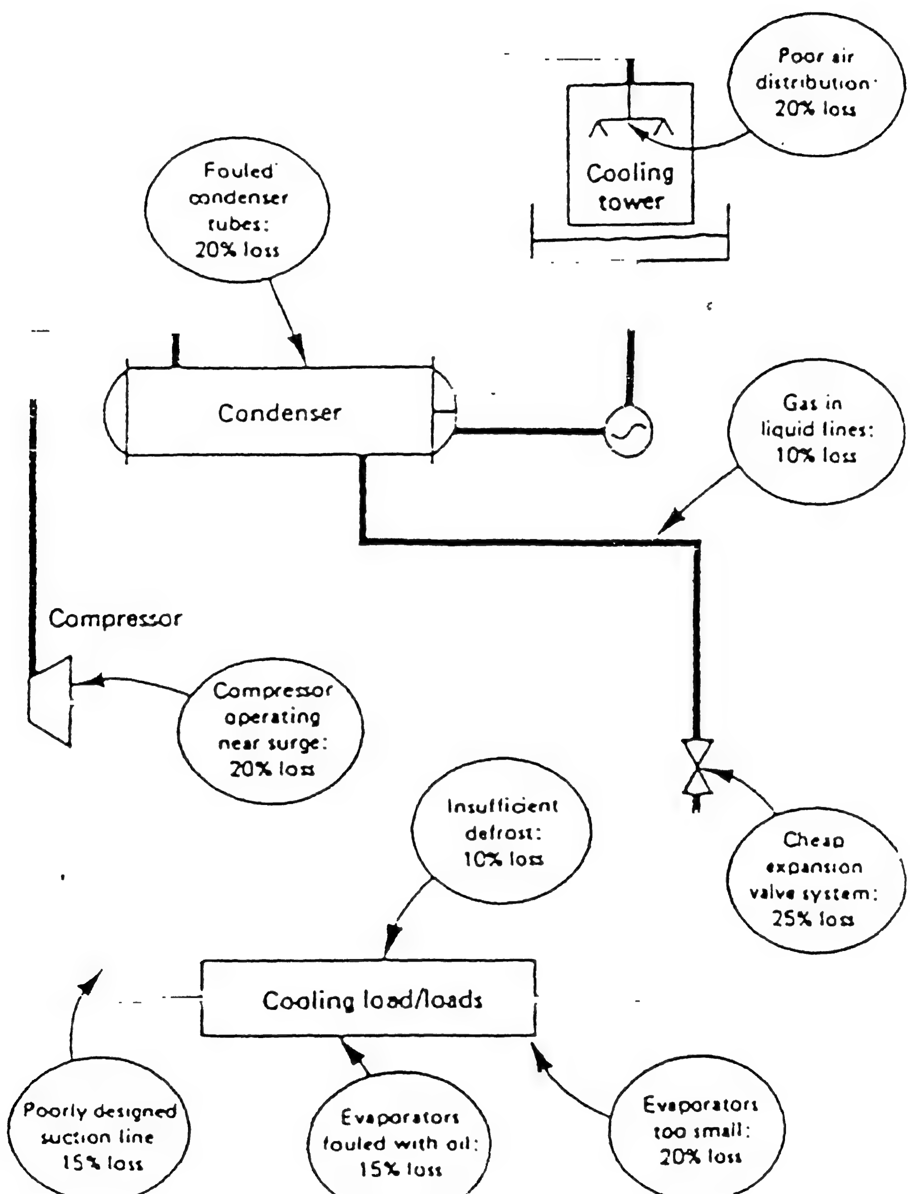
ENERGY CONSUMPTION

MONTHS	SERVICES kWh	PRODUCTION Nos
Nov 90	410842	217623
Dec 90	384484	248001
Jan 91	342317	208178
Apr 90	575861	181749
May 90	494716	253974
Jun 90	452649	206971

Regression Output:(1990-91)

Constant	762036.3
Std Err of Y Est	95035.01
R Squared	0.042487
No. of Observations	12
Degrees of Freedom	10

X Coefficient(s)	705.1561
Std Err of Coef.	1058.582



The diagram of a 'typical' refrigeration plant highlights those areas where losses often occur, and gives an average percentage loss of efficiency for each problem area.

EXAMPLE OF DIAGRAM FOR CONTROLLING
COOLING TOWER FAN AND BY-PASS VALVE
TO CONTROL CONDENSING TEMPERATURE

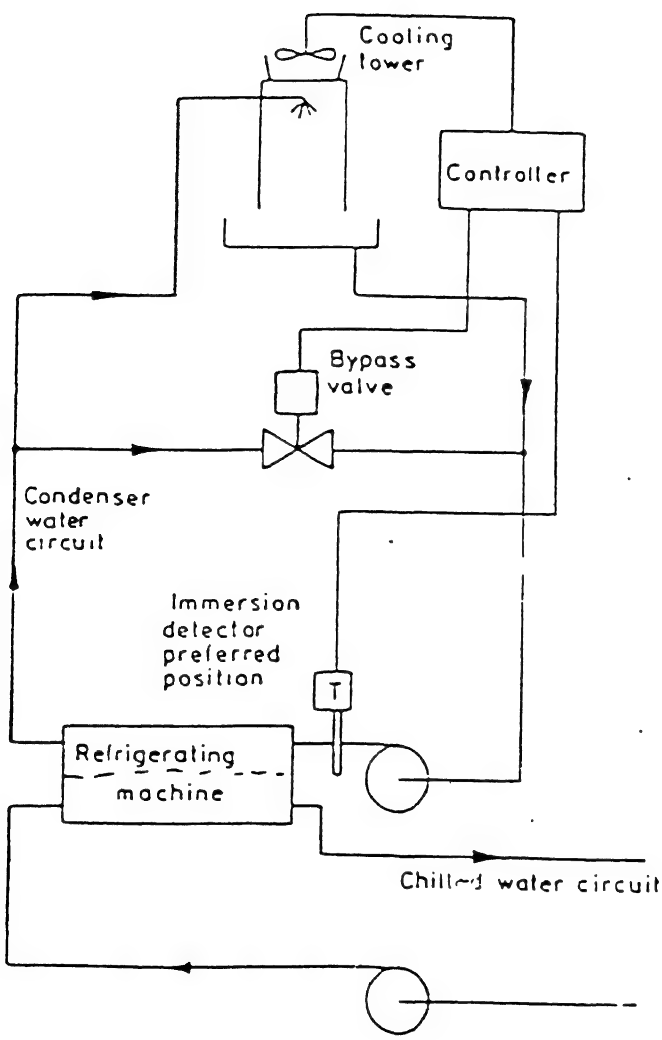


Fig.1

PART LOAD SYSTEM PERFORMANCE

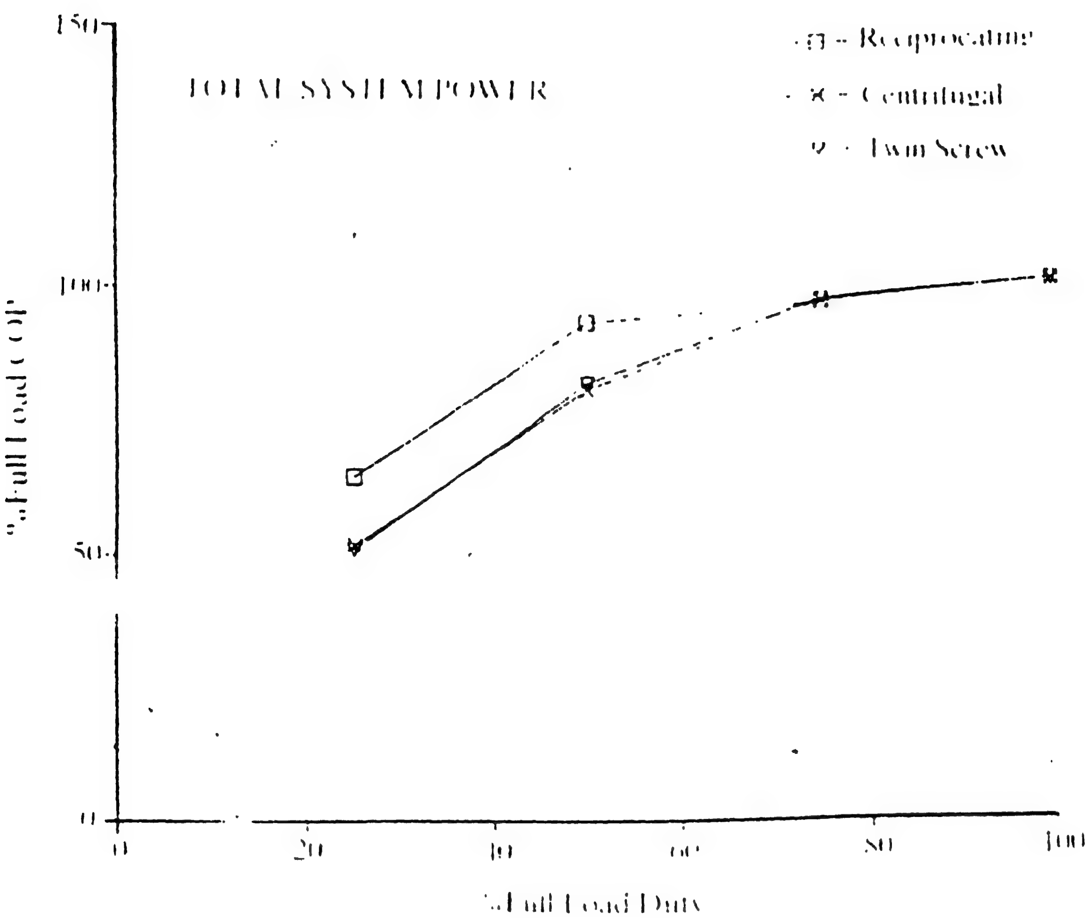


Fig.2

TYPICAL CHILLED WATER INSTALLATION
FOR PROCESS APPLICATION

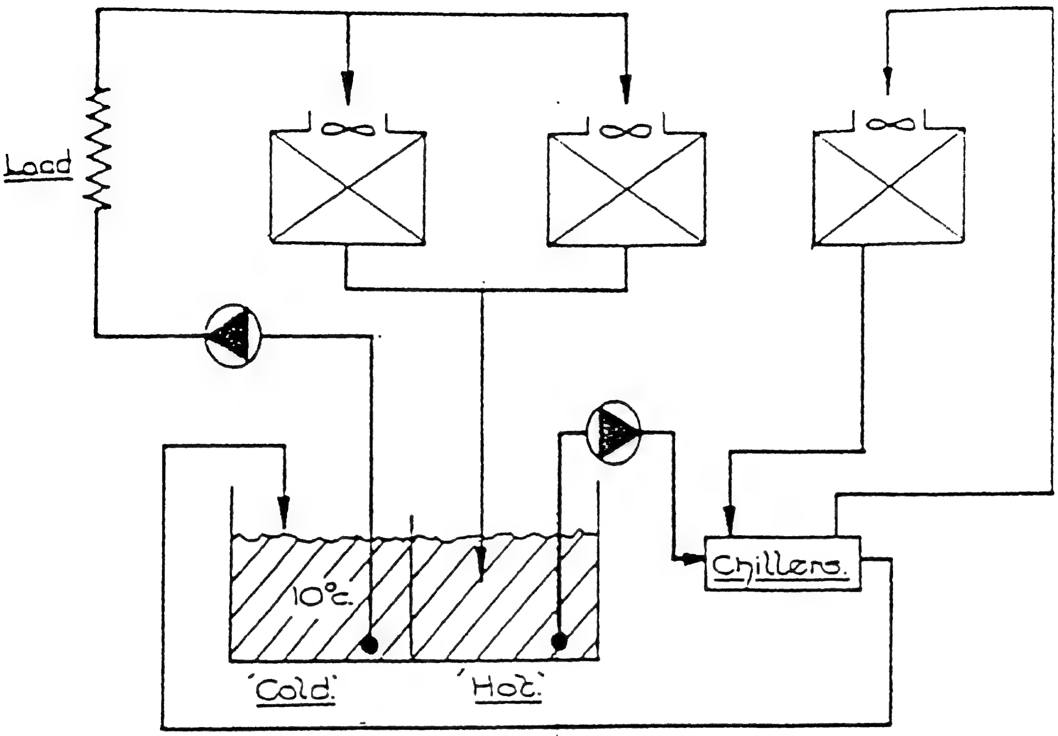


Fig. 3

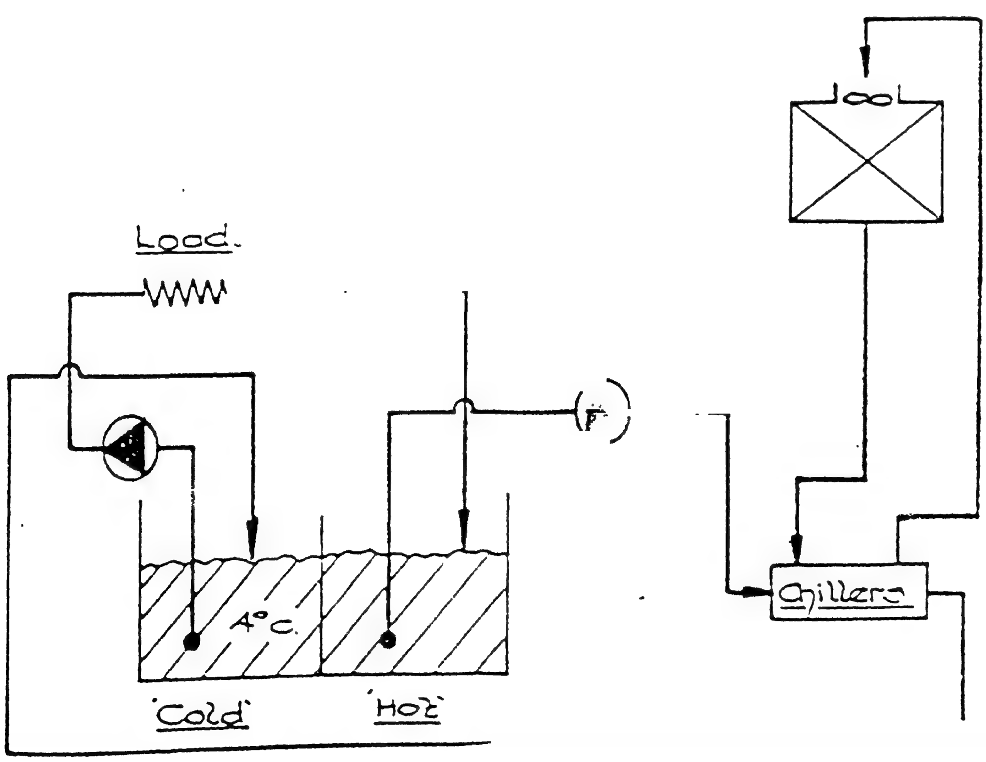
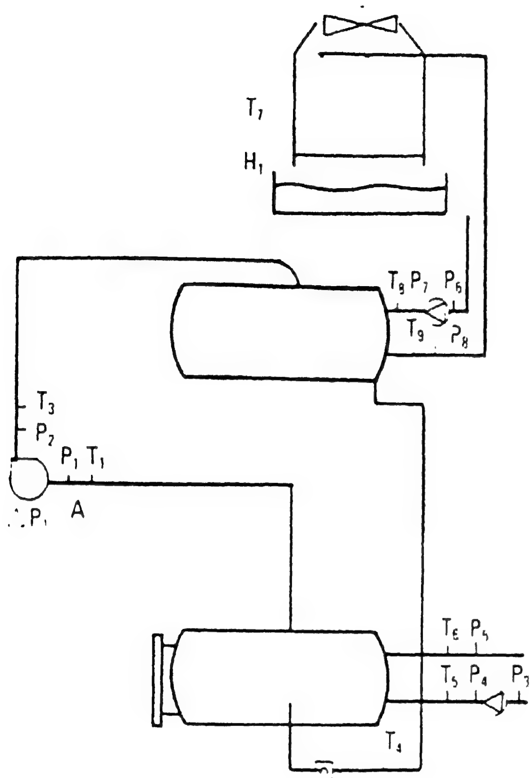


Fig. 4

INSTRUMENTATION REQUIREMENTS FOR WATERCHILLER WITH COOLING TOWER



represents a liquid chiller with an H.P. Float valve, a shell and tube evaporator and shell and tube condenser rejecting heat to a cooling tower. The compressor is a centrifugal unit.

INSTRUMENTATION

COOLING TOWER

- T_7 AMBIENT TEMPERATURE
- H. AMBIENT HUMIDITY OR WET BULB TEMPERATURE
- FAN STATUS (RUN/STOP/TRIP)

SHELL AND TUBE CONDENSER

- PUMP STATUS
- P_6 PUMP INLET PRESSURE
- P_7 PUMP EXIT PRESSURE
- T_8 CONDENSER INLET WATER TEMPERATURE
- P_7 CONDENSER INLET WATER PRESSURE
- T_9 CONDENSER EXIT WATER TEMPERATURE
- P_8 CONDENSER EXIT WATER PRESSURE

CENTRIFUGAL COMPRESSOR

- P_1 COMPRESSOR SUCTION PRESSURE
- T_1 COMPRESSOR SUCTION TEMPERATURE
- P_2 COMPRESSOR DISCHARGE PRESSURE
- T_2 COMPRESSOR DISCHARGE TEMPERATURE
- ΔP_1 COMPRESSOR OIL DIFFERENTIAL PRESSURE
- COMPRESSOR INLET GUIDE VANE POSITION
- A COMPRESSOR MOTOR AMPS
- COMPRESSOR HOURS RUN

SHELL AND TUBE EVAPORATOR

- T_4 LIQUID LINE TEMPERATURE
- P_3 CHILLED WATER PUMP SUCTION
- P_4 DISCHARGE
- T_5 EVAPORATOR WATER INLET TEMPERATURE
- T_6 EVAPORATOR WATER EXIT TEMPERATURE
- EVAPORATOR REFRIGERANT LEVEL
- P_5 EVAPORATOR WATER EXIT PRESSURE

Fig. 5

Fig.6

DATE	TIME	COMPRESSOR								
		HOURS RUN	AMPS	SUCTION TEMPERATURE SATURATED P1	SUCTION TEMPERATURE ACTUAL T1	DISCHARGE SATURATED P2	TEMPERATURE ACTUAL T2	LIQUID LINE TEMPERATURE T3	COMPRESSOR LOADING %	OIL DIFF PRESSURE
RECOMMENDED VALUE →				1° to 5°	P1+ 5° to P1+ 10°			P2 - 2° to P2 - 5°		> 3 bar
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SPECIMEN LOG SHEET

Fig. 7

DATE	TIME	CONDENSER							EVAPORATOR					
		CONDENSING SATURATE P2	LIQUID LINE TEMP T3	WATER INLET PRES P7	WATER INLET TEMP T6	WATER EXIT PRES P8	WATER EXIT TEMP T7	PUMP INLET PRES. P6	EVAPORATING SATURATED P1	WATER INLET PRES. P4	WATER INLET TEMP T4	WATER EXIT PRES. P5	WATER EXIT TEMP. T5	PUMP INLET PRES. P3
RECOMMENDED VALUE →			P2 - 2° to P2 - 5°	2.8 bar		2.3 bar		0.8 bar	1° to 5°	2.5 bar	7° to 10°	2.0 bar	5°	0.8 bar
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.5	[illegible]	[illegible]	2.4	[illegible]	[illegible]	[illegible]	4.9	[illegible]

SPECIMEN LOG SHEET

SECTION - VI

COMPRESSED AIR SYSTEM

COMPRESSED AIR SYSTEM

CONTENTS

		Page No.
1.0	FACILITY DESCRIPTION	1
	A. GAS PLANT	1
	B. ENGINEERING SERVICES (EQUIPMENT DIVISION)	2
2.0	TESTS, MEASUREMENTS & ANALYSIS	3
3.0	AIR DISTRIBUTION SYSTEM	6
4.0	RECOMMENDATIONS	7
5.0	ANNEXURES - I	12
6.0	TABLE 1	24
7.0	CHARTS	25

BHARAT ELECTRONICS LTD

ENERGY AUDIT REPORT

AIR COMPRESSORS

1.0 FACILITY DESCRIPTION

The company has a very large requirement of compressed air. The compressed air is generated at two locations and supplied to the users departments which are spread out, through a distribution pipeline of about 4 k.m. length.

The two centralised compressor rooms are:

a) Gas plant (Components division)

b) Engineering Services (Equipment division)

A GAS PLANT

The compressor room at the gas plant supplies requirements to eleven component manufacturing units in TV tube, Silicon devices and transmitting tube departments.

There are five compressors of different makes and sizes. Details of compressors in this location are given in Annexure I.

Air is compressed at 7 Kg/cm2 pressure.

Air is distributed by two separate pipe lines. One caters to the departments where extra dry air is required. This is done by passing it through a molecular sieve regenerative type air dryer. In case of normal air supply, the moisture removal is done in the after cooler and also in the air receivers, before distribution. In such cases , several departments have their molecular sieve regenerative air dryers installed locally.

The plant personnel have made a study with regard to supply pressure of compressed air to departments. They have come to a conclusion that supply pressure of 5.5 Kg/cm2 would be adequate in case of some departments, as against the present supply pressure of 7 Kg/cm2. This is expected to result in considerable energy savings.

B ENGINEERING SERVICES (EQUIPMENT DIVISION)

This centralised compressed air system caters to mainly equipment division. The departments to which compressed air is supplied are Radar, H.F, LPE, BTV, etc.,

There are in all five compressors in this department. Air is supplied at 10 Kg/cm2 to departments like PCB etc., where extra dry air is required after passing it through a molecular sieve type drier. For other departments air at 7 Kg/Sq.cm is supplied by normal moisture separation in after cooler and air receiver.

The details of various compressors are given in Annexure - II.

Out of the above Khosla No.3 and No. 4 of 50 HP capacity each are used exclusively for supplying dry air which is done by means of regenerative type dryer. However, only one of the two is operated at a time.

Out of the balance three compressors only two are in operation at a given time. Further it was also observed that the cooling water circulated through the compressor jackets, inter coolers and after coolers is cooled outside the E & S department in a cooling tower and then recirculated. The plant staff have been successfull in saving energy by switching off the air blower motor in the cooling tower with out any adverse affect on the efficiency of cooling. However at times when the ambient temperatures are very high the blower has to be switched on for a short time.

2.0 TESTS, MEASUREMENTS & ANALYSIS:

Various measurements & tests on the compressed air systems were carried out as under :

a. Current recording:

By using a strip chart current recorder, measurement of current were recorded over a period of time. This was to compare the current drawn by the electric motors with motor specifications. The recording reveals the power consumption, the loading and unloading of the motor. These are shown in exhibit No.1.

b. Power Analyser:

The instantaneous readings of various electrical parameters like KW KVA, current frequency, power factor, were measured with a clip on type power analyser. By noting these parameters, it is possible to gauge the health of electric motor. The readings are fed into the computer and by means of a special programme, analysis of performance of all electic motors has been made. These are Tabulated in Table 1.

c. Free Air discharge capacity tests:

Each compressor was tested to know whether it delivers the specified F.A.D capacity or not. This was carried but by first emptying air receiver and closing all the outlets valves. The compressor was started and as soon as the electric motor speed stabilised the load was given on compressors. The time was measured from this moment upto the moment the full set pressure was reached and the compressor unloaded.

The calculations were then made using the following formula:

$$\text{Free air discharge capacity of air compressor VC} = \frac{P2-P1}{P1} \times \frac{VR}{time}$$

Where P2 = Final pressure in Kg/sq.cm
P1 = Initial ambient pressure
VR = Volume of air receiver in m3
VC = F.A.D capacity in m3/sec

By conducting the above test it is possible to know whether compressor is delivering the specified quantity of air. The detailed calculations are given in Annexure III for ES Department and Annexure IV for Gas Plant.

d. No Load test :

This test is carried out to find out the amount of air leakage in the distribution network. This is carried out as follows :

With all air oporated equipment shut off, run the air compressor until the system reaches full pressure and the compressor unloads, this time is noted. Due to air leaks the system pressure will gradually fall, and the compressor will come on load again, this time is noted. The period for which compressor is "on load" and "off load" at least 4 times and the mean value of each is calculated. Power wasted is obtained as follows :-

Let T minutes = Time "on Load"

Let t minutes = Time "off Load"

Let Q = Delivered air capacity of compressor in m3/sec

Then L = Total system leakge in m3 /sec

$$= \frac{Q \times T}{(T + t)} \quad m3$$

And Power is wasted is $= \frac{L}{1000 \times 3}$ $\frac{KW}{}$

No load tests were carried out in both Gas plant and ES Compressors to find out the amount of air leaking out of system under no load conditions. This was done on a sunday when the factory had a holiday to ensure that there was no compressed air consumption at the usage point. Maintenance personnel were instructed to close all the valves at the consuming points.

Since it was observed that only a few compressors do loading and unloading operations automaticaly. It was decided to carryout the test by charging the pipe distribution system with compressed air upto the working pressure and then switching off the compressors. The time taken to charge the system and then time taken for the pressure to drop between two known pressures were recorded. It was necessary to run more than one compressor for the purpose since capacity of one compressor was found not sufficient to bring up the line pressure to the operating level.

The details of tests and calculations are given in Annexure V for ES department and in Annexure VI for Gas Plant.

AIR DISTRIBUTION SYSTEM:

It was observed that compressed air is distributed by a 6" pipe which is laid underground and also by 2" pipe line for dry air.

Underground pipes offer a number of disadvantages as they are difficult to maintain and to detect any air leaks. Water accumulation is also common in underground pipes and this will lead to a lot of moisture carryover besides rusting of the pipes. It is difficult to remove water from the underground pipes as seldom proper arrangements/devices are fitted for draining out this water.

However it was noted that steps are being taken to change over tp overhead pipes. While designing the new piping network provision for moisture separators, automatic drain traps etc, should be made at suitable places in view of long distances involved. Proper slope, normally 1 metre drop for 100 metre length, in the direction of air flow will also help in water running down. Provision should be made to collect it in pockets where air traps should be fixed with a strainer to protect the trap getting clogged and getting jammed. Improper installations of traps was observed at several places which were not woking. In case of traps on air receiver tanks, it is essential to have balancing pressure pipes to avoid traps getting air locked.

Air distribution network could not be studied in depth due to non-availability of any layout drawings for compressed air system. It was understood that over the years several new tappings have been taken from the existing pipes. This would have resulted in gross undersizing of pipes for the present consumption pattern. This will result in high pressure drops and loss of energy due to high air velocities in pipes. It is therefore advisible to properly design the distribution network.

As a sample study, the `Low power Equipment Division´ was visited where considerable amount of compressed air is used for various purposes. It was observed that there is a `ring main´ in the department for compressed air, which is a good practice. However, it was observed that amlost all the tappings are taken from the bottom of the pipe line. This should be completely avoided as any condensed water in pipes will be carried over into branch line along with air. The tappings should be taken from the top of the pipe. The pipes should also be sloping towards the direction of flow. The dead end and take off "T" joints should also be given proper pockets to collect the water which should be drained by means of an automatic drain trap.

4.0 RECOMMENDATIONS

4.1 Air inlet temperatures were observed to be too high. It was observed that air inlets to all compressors is situated close to the compressors. Further a number of compressors are situated in a cramped small place (Gas plant). This has resulted in the room temperature rising upto 44 deg.C whereas the outside temperature at the same time was found to be only 32 deg.C. This will result in an additional power consumption of nearly 3%, as for every 4 deg.C rise in outlet air temperature there is 1% increase in power requirement. This can be avoided by providing suitable ducting to draw intake air from outside the building. In the gas plant there are three compressors working at a given time, whose total power requirement is 470 KW a 3% savings will be 14.1 KW.

Hence taking 75% utilisation, the savings with this measure would be around Rs.71,000 per annum.

4.2 Further it was also observed that there was little cross ventilation int he compressor rooms. This was very evident in the E & S compressor room where the wind blows from the backside to the frontside. Since there are no suitable windows at

the backside natural draft is prevented thus raising the room temperature. Even the existing windows on the side walls are kept closed. This should be rectified by providing windows and ventilators on the back side wall and keeping all the existing windows open. The room temperature was found to be at least 5°C higher than the outside tempeature. The total power consumed in E & S compressor room is about 409 KW from any three compressors and a 2 percent savings due to air inlet temperature being lowered will result in a savings of about 8 KW.

Hence taking 75% utilisation, the above measure would result in a saving of Rs.41,000 per annum.

.3 To consider cooling of intake air to nearly - 25 deg.C by using R22 refrigeration system. This will completely eliminate traces of moisture in the air and the following advantages will occur :

i. Due to complete removal of moisture, there will be more air available for a given volume of air, as otherwise partial volume in air is occupied by water vapour.

ii. The amount of air delivered is increased due to higher density of air at lower temperatures.

iii. Dust present in air will be trapped in ice during freezing. This acts as filter and will eliminate the need for conventional filters which offer resistance to air flow.

iv. After coolers and dryers are also eliminated, thus saving on capital costs (atleast for new installations).

All the above would result in nearly 25 to 30% savings in the energy requirements. In this connection we refer to a case study of a project supported by the commission of the European Community in UK.

4.4 There is considerable energy wasted especially in the Gas plant, in running the compressor on `unload´ condition ocassionally, which can be almost 75%.of full load condition. As such Speed control of electrical motor by electronic devices should be considered at least for large compressors.. These devices allow conventional AC induction motors to operate at variable speed mode at high efficiency. These also provide soft start feature. This allows the compressors to stop completely and start again more frequently without damaging the motor.

4.5 Reduction of air pressure required should be considered actively. In most cases the compressed air will be required at a lower pressure than what is produced. It is possible to do the same work at say 5.5 Kg/sq.cm pressure than 7.0 kg/sq cm. As an example this reduction in delivery pressure of compressor can reduce the power requirement to nearly 11 percent for 2 stage compressor.

4.6 Operating individual devices at the less than the line pressure. Even local pressure reduction should be considered at utilisation point if the line pressure is at a higher pressure than what may be essential. By installing a pressure regulator and feeding air at say 5.0 Kg/sq,cm from the line pressure of 7 Kg/sq.cm, there will be energy saving of nearly 24 percent.

4.7 It was observed that there is good consiousness amongst the staff to stop all leakages in the pipes and from other fittings. Considerable savings can be achieved by proper maintaining these fittings from leaking. The table below gives approximate power wasted by leaks of various sizes at the normal airline pressure of 7 Bar.

TABLE

Hole diameter mm	inch	Air leakage at 7 bar dm3/sec.	cfm	Power required to compress air being wasted. KW
0.4	1.64	0.2	0.4	0.1
1.6	1/16	3.1	6.5	1.0
3.0	1/8	11.0	23.2	3.5

b. Because of the above reason reduction of nozzle size should be considered for air cleaning nozzles and air jets which are only used for cleaning purposes. By recuding the air pressure and reducing the hole size for such application, energy savings can be achieved in two ways.

From the analysis of current recordings and readings taken by power anaysers the following recommendations to make on the electrical side.

4.8 All the compressor motors, both at the gas plant and at E & S compressor room are running at a very low power factor. The maximum P.F is only 0.53. Energy losses can be reduced by installing, capacitors of suitable capacity at the motors terminals.

4.9 The supply voltages to the motors are found to be less as compared to the motor specifications. This needs to be looked into and can be enhanced by changing the supply transformer tapping positions.

In view of heavy electrical loads at both the compressor rooms, a separate transformer catering to only compressors may be considered as long time planning along with grouping of electric motors of similar voltage specifications. Tap position management, easier .

4.10 From the "No Load Test" carried out in both Gas plant and E S Department compressors it is seen that due to line leakges there is almost 109 KW and 106 KW wastage of energy respectively. This corresponds to Rs.7.32 lakhs and Rs.7.12 lakhs per annum. By reducing the leakges (ideally at 5 to 10%) and assuming about 60% loading factor on compressors, it is possible to save nearly Rs.3.66 lakhs/annum and Rs.3.56 lakhs per annum respecitvely.

4.11 In view of vast network of distribution piping and corresponding losses, decentralising of compressors may be considered. A detailed techno-economic study may be done by taking into consideration various aspects like operations, maintenance strategies, etc.,

4.12 It is recommended to install individual energy meters for all compressors. By monitoring energy consumption on monthly basis, it is possible to estimate the losses in compressed air system.

ANNEXURE I

LIST OF AIR-COMPRESSORS IN GAS PLANT

1. IHJ-I

Japanese make
Compressor: capacity : 1000 m^3/hour.
Discharge air pressure :7 Kg/sq.cm two stage, twin cylinder.
Electric motor:100 KW, 178 Amps, 3 phase, 415V.

2. IHJ-II

Same as IHJ-I but presently under maintenance.

3. Khosla I

Compressor : two stage, twin cylinder
capacity : 29.2 m3/min
Pressure : 8 Kg/sq,cm
Electric motor : 250 HP/184 KW, 315 Amps. 415 V

4. Khosla II:

Compressor : Two stage, twin cylinder
Capacity : 28.32 m3/min
Electric motor : 250 HP/185 KW, 330 Amps, 3 phase, 415 volts.

5. Kirloskar pneumatics:

Compressor: Two stage, twin cylinder
capacity:28.1 m3/min, pressure:8.5Kg/cm2

Electric motor: KW 187, 314 Amps, 3 phase, 400 V.

ANNEXURE II

LIST OF AIR COMPRESSORS IN E S DEPARTMENT

1. Khosla No 2:

Compressor : capacity : 28.32m3/min two stage, twin cylinder
Pressure: 8 Kg/sq.cm
Electric motor 250 HP/185 KW, 330 Amps, 3 phase 415 V

2. Khosla No 3:

Compressor: Two stage, twin cylinder
Capacity: 3.83 m3/min
Pressure : 10.5 Kg/sq.cm
Electric motor: 50 HP/37 KW, 3 phase, 415 volts

3. Khosla No.4:

Compressor: Two stage, twin cylinder
Capacity : 3.83 m3/min, pressure:10.5 kg/sq.cm
Electric motor: 50 HP/37 KW, 68 Amps, 3 phase, 415 Volts

4. Kirloskar No.5:

Compressor : Two stage, twin cylinders
Capacity:28.1 m3/min, pressure:8.5Kg/sq.cm
Electric motor:250 HP/187 KW, 332 Amps, 3 phase, 415 volts

5. Kirloskar No.6:

Compressor: Two stage, twin cylinders
Capacity:28.1m3/min, pressure:8.5 Kg/sq.cm
Electric motor :187 KW, 382 Amps, 3 phase, 400 volts

ANNEXURE III

FREE AIR DISCHARGE CAPACITY TEST

ENGINEERING SERVICES AIR COMPRESSORS

1. Kirloskar No.6:

VR:Air receiver capacity : 3.5 m3
P2:Final (cut off) air pressure 7.5Kg.sq.cm (8.5Kg/cm2 abs)
t :Time taken to fill the air receiver 47 secs

Therefore F.A.D capacity : $\frac{P2-P1}{P1} \times \frac{VR}{t}$

$= \frac{8.5 - 1}{1} \times \frac{3.5}{4.7}$

$= 0.558 \ m^3/sec$

$= 33.51 \ m^3/min$

The capacity F.A.D. capacity as per the specifications is 28.1m3/min. Hence the compressor is in good condition.

2. Kirloskar No.5:

VR = $3 \ m^3$

P2 = $8.5 \ Kg/cm^2$ (9.5 Abs)

$t = 45$ secs

Hence F.A.D capacity $= \dfrac{9.5 - 1}{45} \times 3 = 0.56\ m^3/sec$

$= 33.96$ m3/min.

This compares favourably with the specification of 28.2 m3/min.

3. Khosla No 3

VR = 1.58 m3

Unloading Pressure : 10.5 Kg/cm2 (11.5 abs)

time : 593 secs

Therefore Vc $= \dfrac{11.5 - 1}{1} \times \dfrac{1.58}{593}$

$= 0.0279$ m3/sec

$= 1.67$ m3/min

This is extremely lower than the specified value of 3.83 m3 /min.

During a retest taken on 25.3.91 on the same compressor it was observed that although the set pressure of 10 Kg/cm2 had exceeded (the pressure gauge had range of maximum 10 Kg/cm2 the exact pressure could not be ascertained) and more than 11 minutes had eapsed, the compressor did not unload. This indicates malfunction of governer and should be rectified immediately.

4. Khosle No.4:

VR : $0.48\ m^3$
Unloading pressure : $10\ Kg/cm^2$ (11 abs.)
Time : 140 secs

$$\text{Therefore } Vc = \frac{11-1}{1} \times \frac{0.48}{140}$$

$= 0.034\ m^3/sec$

$= 2.05\ m^3/min$

Whereas the specification is $3.83\ m^3/min$ and hence the Compressor needs overhauling and checkup of inlet/outlet valves etc.,

5. Khosla No.2

VR = $3\ m^3$

P2 = $7.5\ Kg/cm^2$ (8.5 abs)

time = 52 secs

$$\text{Therefore } VC = \frac{8.5 - 1}{1} \times \frac{3}{52} = 0.432\ m^3/sec$$

$$= 25.92\ m^3/min$$

The specified F.A.D is given as $28.32\ m^3/min$ and hence the compressor needs attention.

ANNEXURE IV

FREE AIR DISCHARGE CAPACITY TEST

GAS PLANT AIR COMPRESSORS

1. 1HJ - I

VR = Air receiver capacity : 2.47 m3

P2 = Find 1 (cut-off) air pressure = 7 Kg/Sq.cm
(8 Kg/Sq.cm abs)

t = time taken to fill the air receiver = 78 sec.

Therefore F.A.D.Capacity : - $\frac{P2 - P1}{P1} \times \frac{VR}{t}$

$= \frac{8 - 1}{1} \times \frac{2.47}{78}$

= 0.22 m3/sec

= 792 m3/hour

As per the FAD capacity specification by the manufacturer the same should be 1000 m3/Hour and hence highly derated. The same needs to be looked into.

It was also observed that there was air leak from gasket of manhole cover in the air receiver.

2. KHOSLA - I

VR = 2.8 m3

P2 = 9.3 Kg/cm2 (10.3 Kg/sq.cm abs.)

t = 75 secs

Hence FAD Capacity $= \frac{P2 - P1}{P1} \times \frac{VR}{t}$

$$\frac{10.3 - 1}{1} \times \frac{2.8}{75}$$

0.3472 m3/sec

= 20.83 m3/min

This is considerably lower than the rated FAD capacity of 29.2 m3/min.

3. KHOSLA - II

VR = 2.8 m3

P2 = 8.2 Kg/cm2 guage (9.2 Kg/cm2 abs)

t = 85 seconds

FAD capacity $= \frac{9.2 - 1}{1} \times \frac{2.8}{85}$

= 0.270 m3/sec

= 16.2 m3/min

The specified F.A.D capacity of this compressor is 28.32 m3/min. and hence the actual F.A.D comes to only 57%.

It was also observed that there was air leakge from one of the glands. Hence this should be immediately looked into :

4. KIRLOSKAR

VR = 3 m3

P2 = 7 Kg/cm2 (guage) = 8 Kg/cm2 (abs)

t = 55 sec

$$\text{F A D capacity} : \frac{8 - 1}{1} \times \frac{3}{55}$$

= 0.381 m3/sec

= 22.9 m3/sec

This is against the specified F.A.D of 28.1 m3/min. and immediately looked into.

ANNEXURE V

E S DEPARTMENT COMPRESSORS

Compressors operated :

	Actual discharge capacity (Please refer Annexure III)
Kirloskar No. 6 (250 HP)	33.51 m3/min
Khosla No. 2 (250 HP)	25.92 m3/min
TOTAL	59.43 m3/min

Average time to fill up from 80 psi to 100 psi pressure (on load time) T: 105 seconds

Average time for pressure to drop from 100 psi to 80 psi t : 220 seconds

Now Q : Delivered free air capacity of compressor

= 59.43 m3/min

= 0.9905 m3/sec

Hence system leakge L = $Q \times \frac{T}{(T + t)}$

$$= \frac{0.9905 \times 105}{(105 + 220)}$$

= 0.320 m3/sec

Hence percent leak is : 0.32/0.9905 x 100

= 32.3% *

* Only the inlet main valves to each departments were closed and not at the consuming points.

This corresponds to nearly 106 KW in losses. Hence for 16 Hrs/day and 300 days/years of working the financial loss will be Rs. 7.12 lakhs.

Hence percent leak is : 0.32/0.9905 x 100 = 32.3%

ANNEXURE VI

GAS PLANT

Compressors operated :

IHJ (75 HP) : 6.66 m3/min

IHJ - I (75 HP) : 13.2 m3/min

Khosla - 1(250 HP): 29.2 m3/min

49.06 m3/min

Average time for filling up the system from 5 Kg/cm2 to 7 Kg/cm2 T : 390 seconds

Average time for pressure to drop from 7 Kg/sq.cm to 5 Kg/Sq.cm : t : 584 seconds

Q = delivered free air capacity : 49.06 m3/min

= 0.817 m3/sec

Hence leakge : $L = Q \times \dfrac{T}{T + t}$

$$= \frac{0.817 \times 390}{(390 + 584)}$$

$$= 0.817 \times \frac{390}{974}$$

= 0.327 m3/sec

Hence percent leak : $\frac{0.327}{0.817} \times 100$

= 40.02%

This corresponds to nearly 109 KW in losses. Hence for 16 Hrs/Day and 300 day/Year working the financial losses will be :Rs.7.32 Lakhs

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TABLE 1

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B.E.L. COMPRESSED AIR SYSTEM

ANALYSIS OF PERFORMANCE OF MOTORS

SLNO	--MOTOR REF-	--H.P.--	---MEASUREMENTS---						---ANALYSIS---		
			-HZ-	VOLTS-	AMPS	P.F.	-KVA-	-KWM	UNDER LOAD%	UNDER VOLT%	REMARKS
1	KHOSLA 1 G P	250.00	48.30	396.62	495.00	0.52	338.40	176.40	0.00	7	LOW P.F.
2	IHJ-1 G P	134.04	48.20	398.36	241.00	0.50	165.00	82.80	0.00	7	LOW P.F.
3	KIRL G P	250.67	48.20	400.09	444.00	0.49	307.80	151.50	0.00	6	LOW P.F.
4	KHOSLA 2 GP	250.00	48.30	400.09	461.00	0.50	320.70	160.80	0.00	6	LOW P.F.
5	KHOSLA 5 ES	50.00	48.10	391.43	85.70	0.39	58.20	22.77	38.95	8	LOW P.F.
6	KHOSLA 3 ES	50.00	48.20	398.36	93.60	0.44	64.20	28.59	0.00	7	LOW P.F.
7	KHOSLA 2 ES	250.00	48.20	401.82	292.00	0.53	202.50	108.00	42.09	6	LOW P.F.
8	KIRL 5 ES	250.67	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100	LOW P.F.
9	KIRL 6 ES	250.67	48.10	386.23	460.00	0.53	310.20	166.20	0.00	10	LOW P.F.

VI/25

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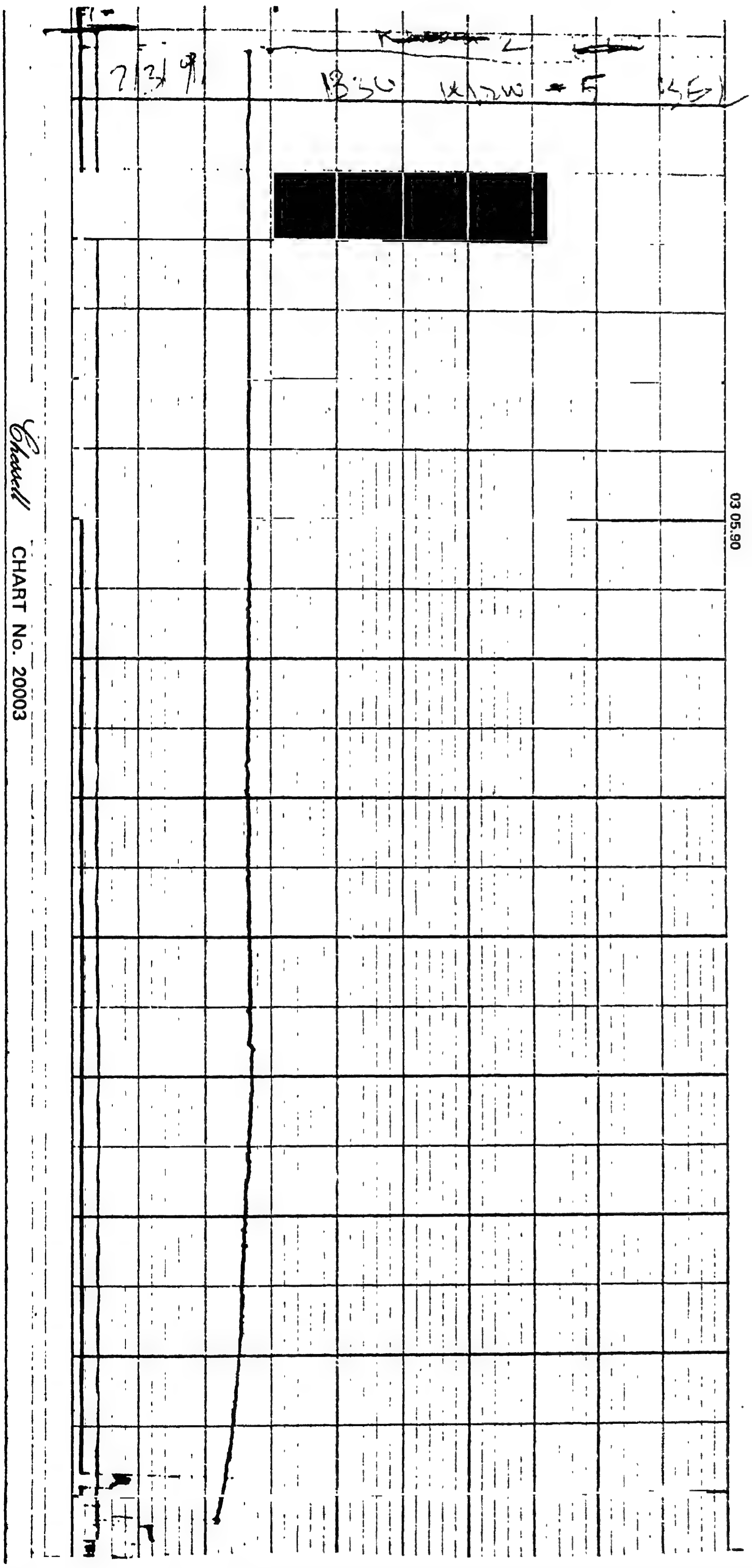
BANGALORE



E & S

KIRLOSKAR NO.5

0-500 AMPS.

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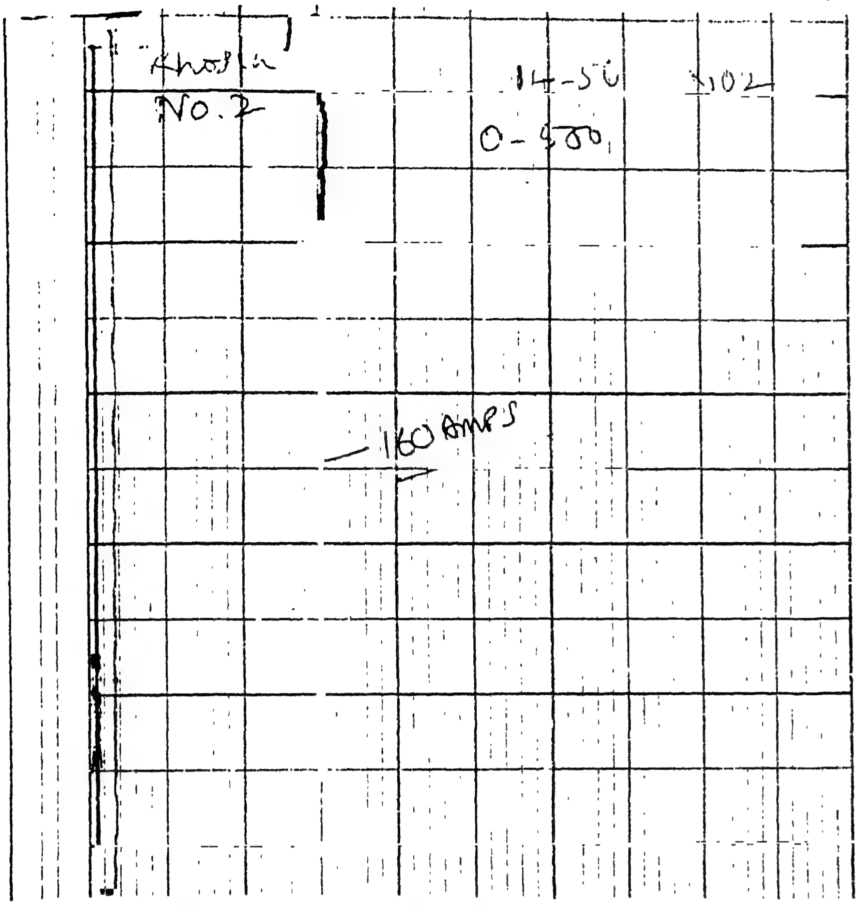
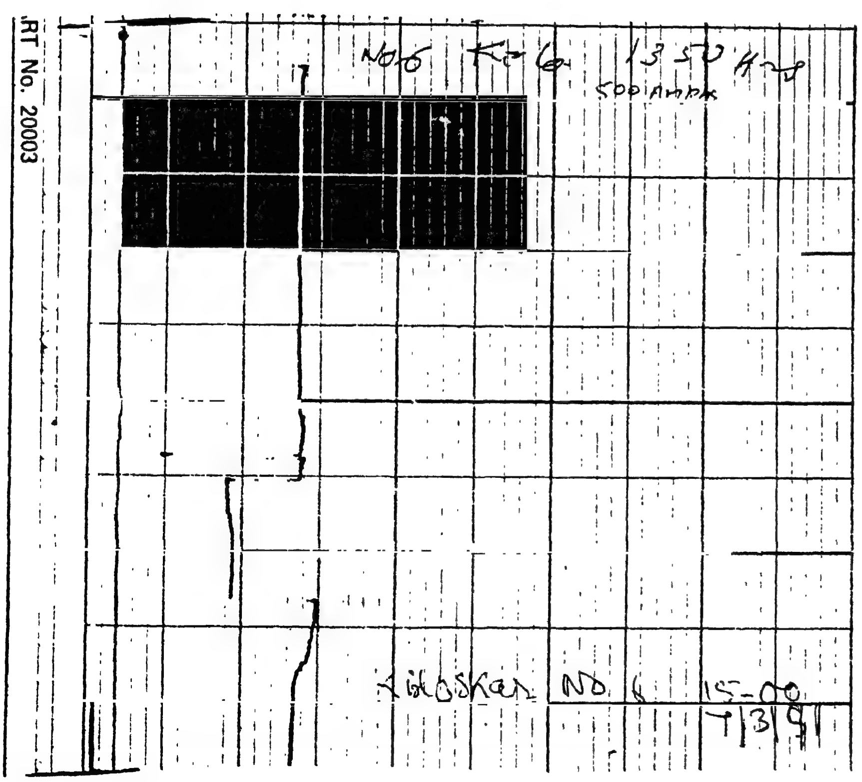
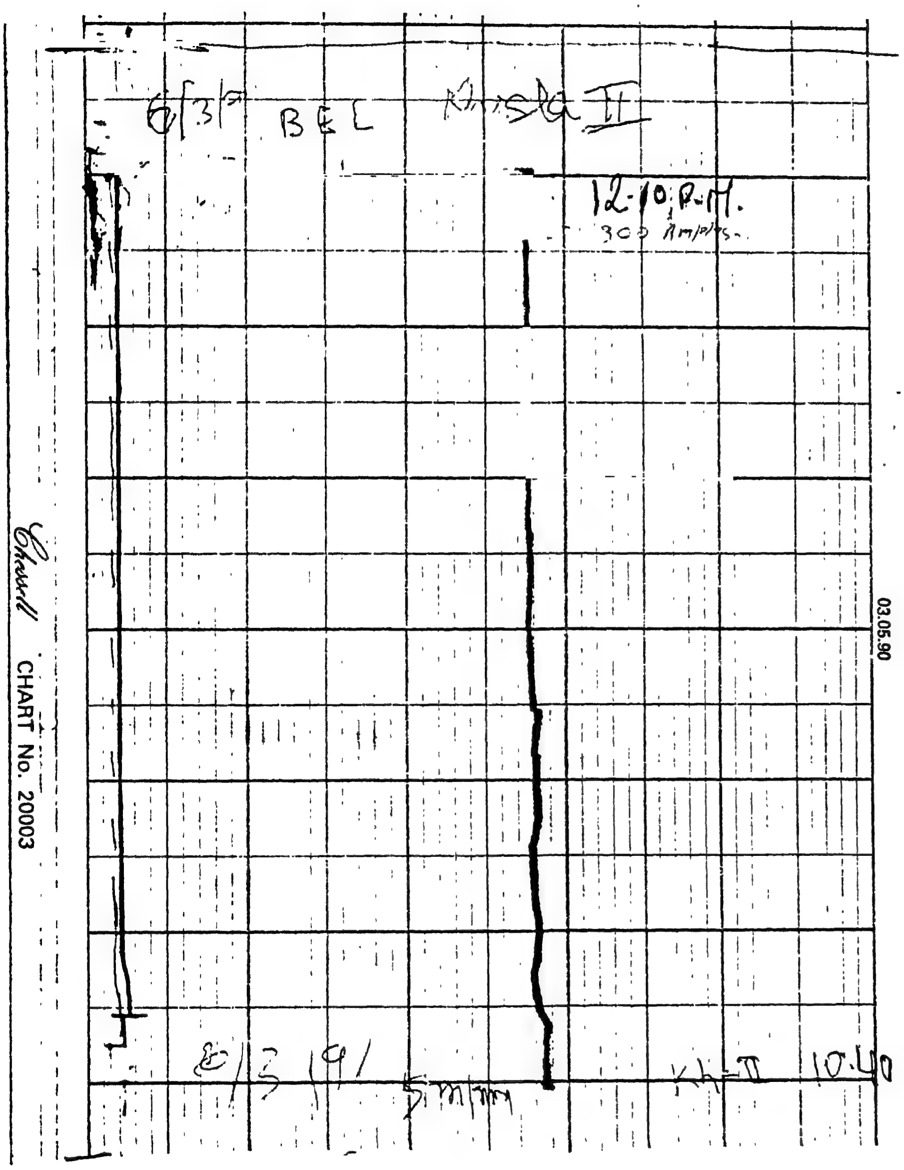


E & S KHOSLA NO.2 0-500 AMPS



E & S
KIRLOSKAR 6
0-500 AMPS



GAS PLANT KHOSLA NO. 2 0-500 AMPS.

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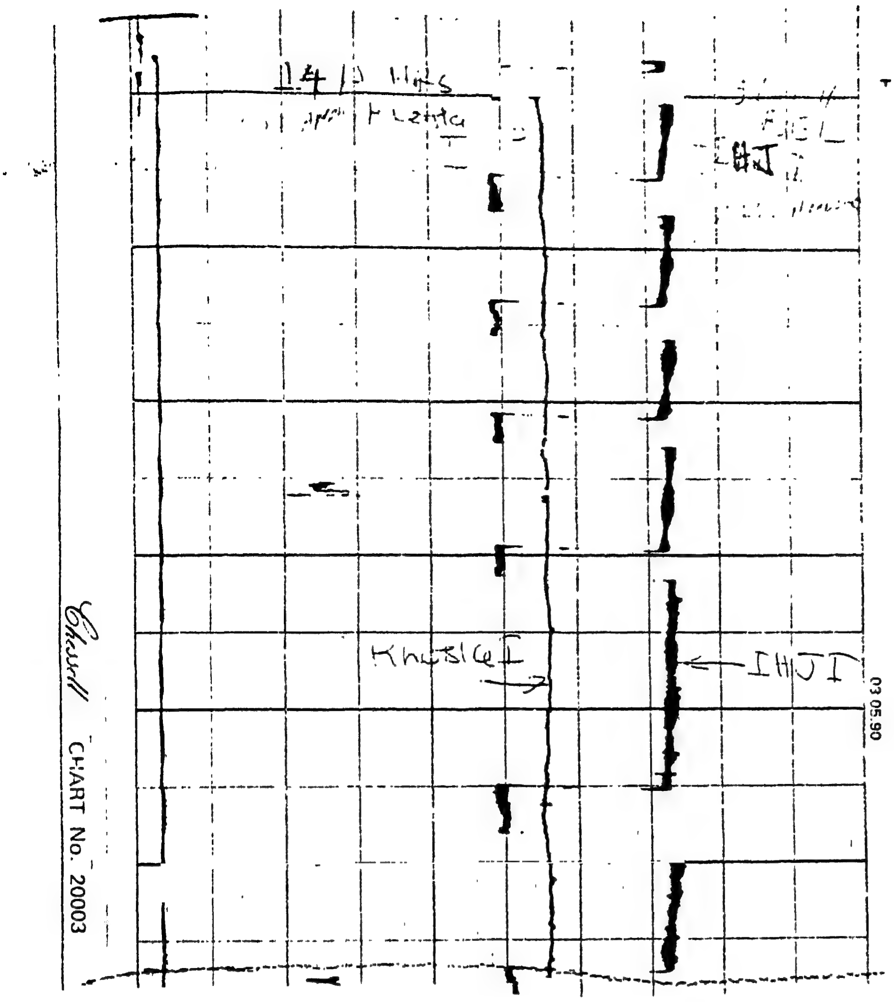
BANGALORE



GAS PLANT

I.H.J. - I 0-250 AMPS

KHOSLA 1 0-500 AMPS

VI/29

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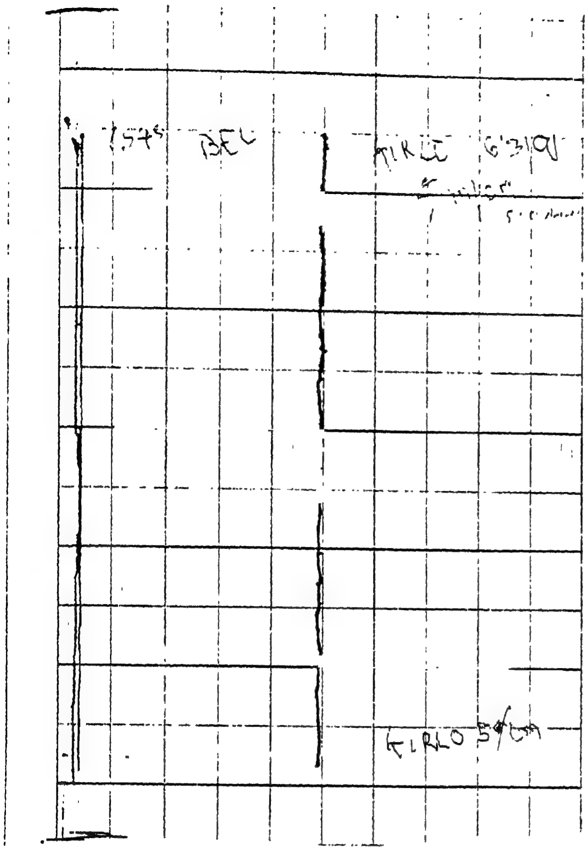
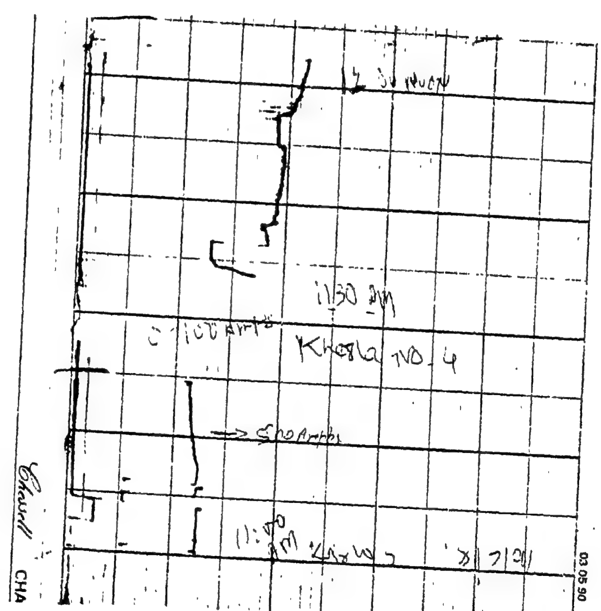


GAS PLANT

KIRLOSKAR
0-500 AMPS.

E & S
KHOSLA NO.4
0-100 AMPS



E & S
KIRLOSKAR NO.5
0-500 AMPS

TATA ENERGY RESEARCH INSTITUTE
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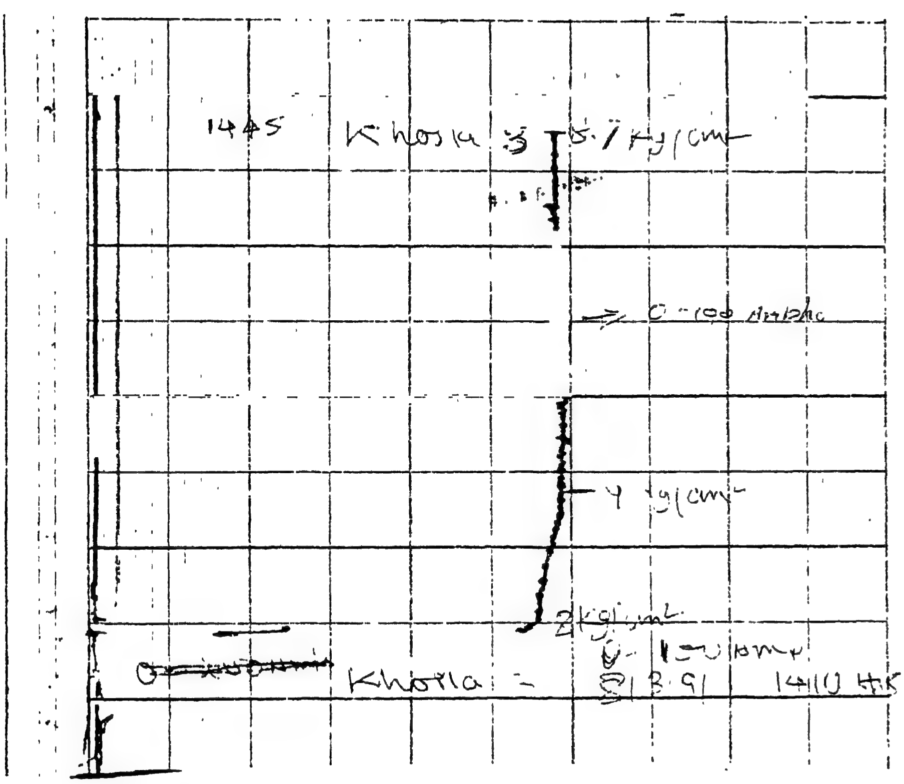

E & S KHOSLA NO. 3 0-100 AMPS

SECTION - VII

DIESEL GENERATING SETS

DIESEL GENERATING SETS

D G Sets are one of the critical pieces of equipment consuming large quantities of energy. The energy audit team has studied various factors influencing the energy efficiency of two D G Sets in the plant. Measurements of exhaust temperature an flue gas composition of two D G Sets were made using portable oxygen analyser and draeger gas testing equipment.

There are total 7 D G sets in the plant, 3 of 2500 kVA, Mitsubishi make and 4 of 1000 kVA, Petbow make. The fuel consumption per D G set is around 530 litres per hour.

Combustion Analysis

DG Set	Flue Gas Temp (^oC)	O_2 %	CO ppm
Mitsubishi 10038	465^oC	9.9	180
PETBOW 2	650^oC	6.6	1000

The specific energy generation ratio (SEGR) of all the DG Sets for the year 1989-90 was around 3.2 which is lower than the value specified by the manufacturers.

There is a heat recovery boiler installed for all the DG sets to recover the heat from the exhaust gases and generate the steam required for the process. The steam is generated at 6-7 kg/cm^2. It was observed during the study that the exhaust temperature even after the heat recovery was as high as 300 ^oC.

OBSERVATIONS & RECOMMENDATIONS

1. Lower specific energy generation ratio indicates that the maintenance of DG sets should be improved.

   Heat transfer surfaces should be periodically cleaned(proper heat transfer to cooling water is required to run DG sets efficiently).

   See Appendix I for operating tips on diesel and lube oil conservation in DG SETS

2. It is observed that the stack gas temperature and CO emmissions are very high in PETBOW2 DG set. It is suggested to check the manufacturer's specification for the exhaust temperature.

   It is recommended tht proper tuning of the generator should be done. High CO emission indicates that overhauling is required.

   Proper tuning of DG sets would reduce both stack temperature and CO level in the exhaust. It should be noted that stack temperature reduction of 1°C saves 430 kg oil per year.

3. The steam line from the heat recovery boiler to the feed water tank at a surface temperature of 123°C was found un-insulated . It is strongly suggested to insulate the hot surfaces to reduce the heat losses and for the safety considerations.

4. The heat recovery boiler efficiency which is 30 % now be improved by atleast 15 % by insulating all the man holes and supporting structure and cleaning the fouled gas side heat transfer surfaces.

APPENDIX -I

Diesel Generator Sets

Operating Tips for Fuel and Lube Efficiency

1. Select proper fuel. If the injection system can tolerate more viscous fuels like LDO, furnace oil or other residual fuels like LSHS or HPS, go for higher viscosity fuels.

2. Ensure proper storage and handling of fuel. Dirt and contamination will make the fuel go off specification.

3. Load the DG set above 50 percent for large D.G.Sets, and above 60 percent for small sets.

4. Ensure proper fuel injection, correct viscosity and temperature, timing, proper mechanical condition of components, and prevent lube contamination.

5. Select proper lubricant. Monitor lubricant condition through regular sampling and analysis of used oil. Ensure proper lubricant cooling and consumption. (Thicker oil cause 2 percent excess fuel consumption).

6. Externally clean the air filters regularly, to ensure proper filteration and cleanliness of intake air.

7. Avoid leakges of fule oil and lube oil, even though they may be of minor nature. They are a major cause for higher fuel and lube consumption.

8. Norrally, engine oils of SAE 40 grades are used in D.G.sets, unless otherwise recommended by the manufacturers. Use of multigrade and higher performance level oils with high detergency, alkalinity reserve and antiwear properties help in both lube and fuel conservation i addition to improving engine mechanical efficiency.

9. Check compression pressure regularly if provision exists. Attend to stuck piston rings, leaky valves, clogged ports, excessive liner and ring wear, etc., promptly.

10. Insulate exhaust piping to reduce air temperature inside the generator room as the higher intake air temperature increases the specific fuel consumption and reduces engine output .(Engine output reduces by about 5 percent for 10^{o}C rise in intake temperature).

11. Avoid exhaust gas temperature above 450^{o}C.High exhaust temperatures due to overload and restricted air supply, could lead to lower fuel efficiency as well as fouling of turbo-chargers.

12. Avoid over lubrication to prevent deposits inside the engine and on the turbo-charger blades.

13. Maintain the cooling circuit system and clean heat exchangers regularly. Meet manufacturer's norms on cooling water temperature, back pressure, flow rate, quality, etc.,

14. Adopt preventive or preferably predictive maintenance programmes.

15. Attempt waste heat recovery, if technically and economically viable.

Measures for Diesel Engine Lubrication Oil Conservation

1. Improve air filtration.

2. Reduce fuel dilution by

   a. ensuring proper atomization
   b. having correct engine temperature
   c. having proper air-fuel ratio
   d. emuring proper crankcase venting
   e. eliminating worn out rings and cylinder liners

3. Check insolubles build-up in oil by using proper air, oil and fuel filters.

4. Reduce oil loss by proper clearance between valve stem and guide.

5. Reduce oil loss past piston by

   a. reducing carbon deposits on top land
   b. avoiding bore polishing and glazing
   c. attending to ring wear

6. Provide by-pass purification system or removeinsolubles by centrifuging.

7. Use long drain oils with improved air and oil filters

8. Monitor TBN values more closely where higher sulphur diesel is used.

9. Switch on to multigrade oils for oil as well as fuel economy.

10. Check for leaks in the lubrication system and attent to them promptly.

11. Change oil on condition basis and not on the thumb rule recommended by oil companies or engine builders. Field oil testing systems are readily available in the country.

12. Oil never deteriorates. It goes off specs temporarily. The drained oil can be re-refined and brought to proper level by appropriate re-refining and reclanation techniques. For further details on refining, consult PCRA booklet titles how to Conserve Lubes' (through recycling). For any further information on this please contact PCRA, New Delhi.

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T E R I
Bangalore.